A-7.2.5 Southern Deep Perched Water

The southern deep perched water includes perched water encountered from 180 ft to 380 ft below land surface. It is primarily associated with the 380-ft interbed and appears to have been recharged by the former percolation ponds. This region includes all well screens located south of the CPP-3 injection well and lower than 4,741 ft elevation. Key observations include

- Perched water has never been observed in half of the southern deep perched water wells. These dry wells included 1781L, 1781M, 1801M, 1802U, 1803L, 1807M, MW-1-1, MW-17-1, PP-CH-1, and PP-SP. The simulated wells were also dry at these locations.
- There is an apparent discrepancy between actual and model interbed elevations in the area of wells 1804L and 1802L. Simulated high saturation elevations were lower in those wells than observed data.
- There were several wells in which perched water was observed but not predicted, again because of the conceptual model for flow in the fractured basalt. These wells with simulated completion intervals in basalt included 1804M, CS-DP-1, CS-CH, and MW-1-4.
- Wells 1802L, MW-17-2, MW-17-4, and PP-DP-4 had intermittent dry periods which were not predicted by the simulated perched water.
- Only well PP-DP-4, which is located near the former percolation ponds, went dry after the percolation pond relocation on August 26, 2002. A decline in simulated perched elevation was not predicted in this well, but a decline in simulated deep perched water was predicted in PP-CH-2 located approximately 40 m higher.

Time series plots illustrating these observations are given in Figures A-7-13 and A-7-14.

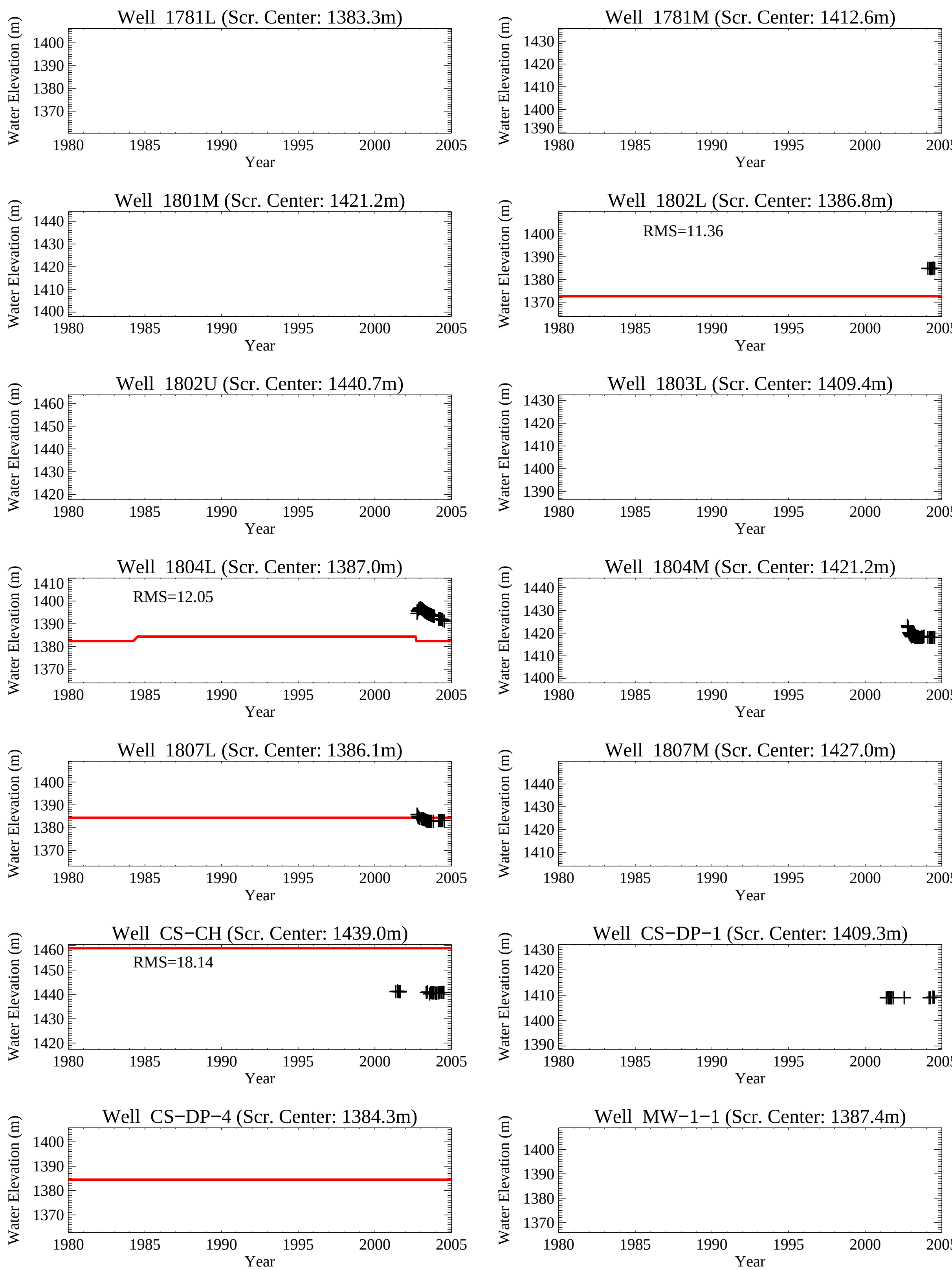

Figure A-7-13. Time series water elevation plots for the southern deep perched water (red line = predicted elevation, back crosses = measured data).

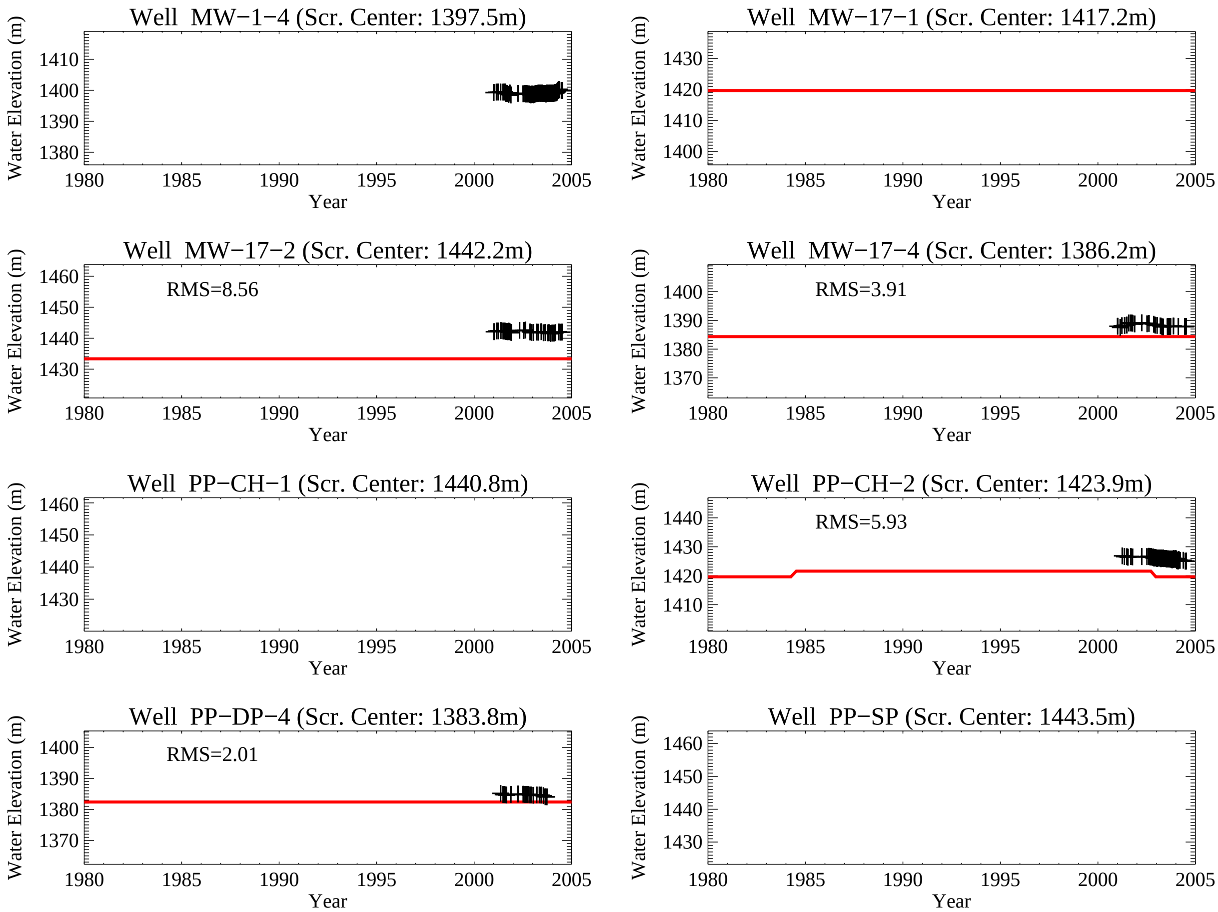

Figure A-7-14. Time series water elevation plots for the southern deep perched water, continued (red line = predicted elevation, back crosses = measured data).

A-7.3 Vadose Zone Transport Calibration

Contaminants in the perched water beneath INTEC have resulted from various leaks and spills during liquid transfer operations in the vicinity of the tank farm and from the disposal of service waste in the vadose zone during the CPP-3 injection well failure. The service waste was the source of most of the tritium, I-129, and nitrate released to the subsurface. The tank farm releases were the source for most of the Sr-90. Comparable amounts of Tc-99 originated from the service waste and from the tank farm releases. Confidence in the Tc-99 service source term is poor because it was never monitored in the service waste and was estimated from far downgradient aquifer concentration ratios (see Section A-9.2).

All of the known releases of H-3, I-129, Sr-90, Tc-99, and nitrate were used in the calibration process. Tank farm releases; the OU 3-13, Group 3, soil sites; and the CPP-3 injection well failure are the dominant source locations in the northern portion of INTEC. The dominant sources in southern INTEC include the discharges in the former percolation ponds, the CPP-02 abandoned french drain located near Building CPP-603, and the OU 3-13, Group 3, soil sites. Most of the perched water concentration data were collected during and after the OU 3-13 RI/BRA and only date back to the early 1990s. Tritium and Sr-90 were often the most analyzed radionuclides, while Tc-99 and I-129 were analyzed less often. Because of the sampling history, matching contaminant arrival in the deep perched water for contaminants originating in the tank farm is difficult. Additionally, the USGS-50 well has been monitored since the late 1960s. However, the arrival signals from tank farm releases have been dominated by the releases to the vadose zone occurring during the CPP-03 injection well failure and during use of the well for service waste disposal. The arrival of tank farm contaminants having a large service waste component and small tank farm component are not visible in USGS-50, because the service waste signal is much larger. The USGS-50 concentration history may not accurately represent travel time through the vadose zone because perched water has been seen cascading down the well bore and attempts at fixing the leaky well bore have been only partially successful.

The calibration results for Tc-99, tritium, I-129, and nitrate are presented in Sections A-7.3.1 through A-7.3.3, respectively. The Sr-90 calibration is presented in Appendix J along with the geochemical model development. Predicted concentration histories in the northern upper shallow, northern lower shallow, northern deep, southern shallow, and southern deep perched water zones are discussed separately in each section. The transport calibration was achieved by adjusting the hydraulic parameters, source term placement, and dispersivity as discussed below:

- The source term placement adjustment was only performed if the release site straddled two model grid blocks. This was the case for Site CPP-31, which was almost evenly divided by two model grid blocks in the east-west direction; placing the CPP-31 source in the east grid block improved agreement in both the western and eastern direction.
- A longitudinal dispersivity of 1 m and transverse dispersivity of 0.1 m provided best agreement between observed and simulated values for all calibration contaminants.

A summary of the calibrated model's transport parameters is presented in Table A-7-2.

Table A-7-2 Calibrated model transport parameters.

Contaminant	Alluvium K_d (mL/g)	Interbed K_d (mL/g)	Basalt K_d (mL/g)	Longitudinal Dispersivity (m)	Transverse Dispersivity (m)
Tc-99	0.	0.	0.	1.	0.1
Sr-90	Variable as predicted by geochemical modeling for CPP-31, 0.25 for all others	22.	0.	1.	0.1
I-129	1.5	0.7	0.	1.	0.1
H-3	0.	0.	0.	1.	0.1
Nitrate	0.1	0.1	0.	1.	0.1

A-7.3.1 Tc-99

The simulated sources of Tc-99 in the vadose zone listed in order of increasing magnitude are the OU 3-13, Group 4, soil sources (0.1 Ci); service waste ponds (1.13 Ci); CPP-3 injection well failure (1.05 Ci); and tank farm sources (3.56 Ci). Tc-99 is primarily produced as a fission product and does not have a naturally occurring background concentration. It is long-lived and is very mobile (zero K_d). Tc-99 was not sampled for regularly, the peak concentrations were often missed, and the concentration history within specific wells is not definitive. Current Tc-99 concentrations in the aquifer beneath northern INTEC are above the MCL and are most likely higher than those resulting from CPP-3 injection well operation, although there are no aquifer monitoring data available during this time period. This suggests that Tc-99 originating from tank farm releases has migrated deep into the vadose zone and is currently contaminating the aquifer beneath INTEC.

Figure A-7-15 illustrates the total simulated rate of Tc-99 arriving in the aquifer over time. Four peak activity periods can be seen in Figure A-7-15. These are the result of the following: (1) the injection well failure during the late 1960s, (2) the service waste ponds during the early 1980s to the early 1990s, (3) the transient Big Lost River recharge during the late 1990s, and (4) the long-term average Big Lost River recharge following the recent hydrologic drought.

The Big Lost River has a large impact on Tc-99 transport. The hydrologic drought during the early 1990s resulted in reduced recharge and a decrease in Tc-99 flux rate. This drought ended in the late 1990s and the year 1999 was the peak flow year for the Big Lost River recorded at Lincoln Boulevard bridge gauge. A sharp increase in Tc-99 arrival occurred as result of the increased recharge and continued until the current hydrologic drought began in the year 2000. The long term average was used to define future Big Lost River flow. Peak transport of Tc-99 from surface sources was predicted to occur during the late 1990s. A second, smaller peak in flux is predicted to occur in the 2004-2010 time period (also see Figure A-7-16). The highest concentrations deep in the vadose zone are predicted to occur just south of the tank farm near the MW-18 monitoring well. The shallow vadose zone contamination located immediately north-west of the former percolation ponds is due to the CPP-22 OU 3-13 soil site (0.1 Ci), which was placed in the model in 1990.

The simulated Tc-99 concentrations in the perched water generally showed good agreement with the sparse observed data. The arithmetic average log RMS and standard deviation for all well locations was 1.14 and 0.6, respectively. The minimum log RMS was 0.19 and the maximum was 2.8. This error represents an average error of one order of magnitude.

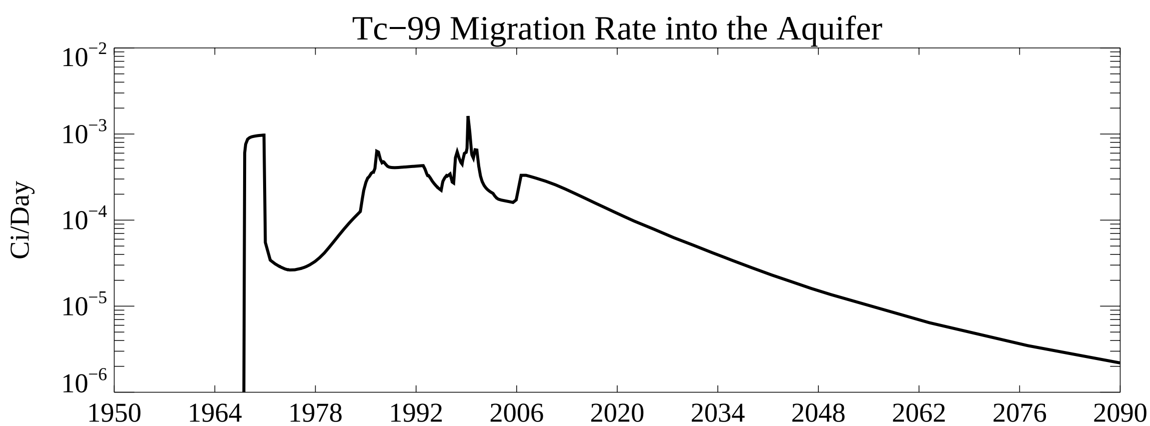

Figure A-7-15. Total flux of Tc-99 entering the aquifer (Ci/day).

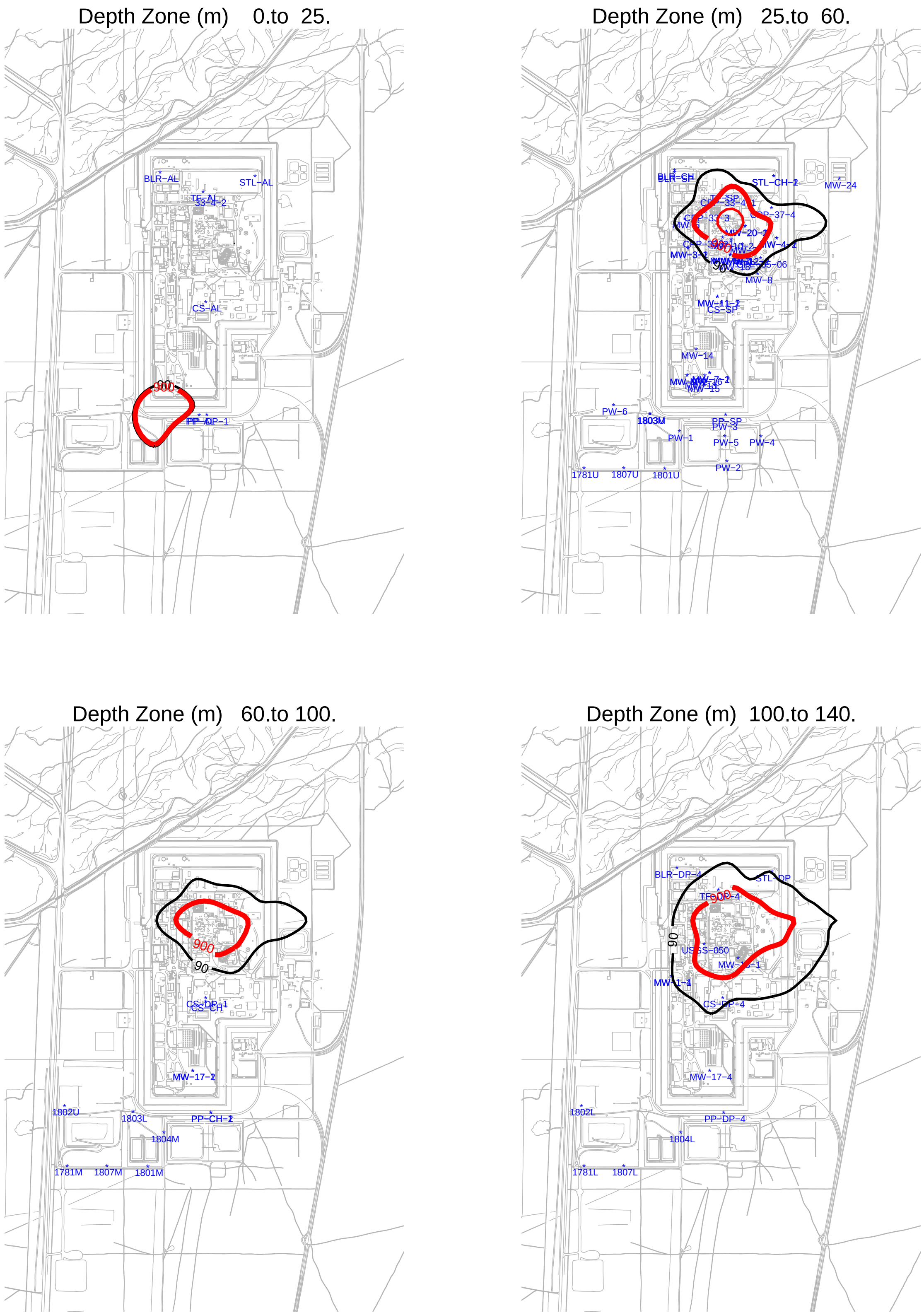

Figure A-7-16. Horizontal extent of simulated Tc-99 at different depth intervals in the vadose zone in 2004 (red isopleth is 900 pCi/L).

A-7.3.1.1 Northern Upper Shallow Perched Water Tc-99

The northern upper shallow perched water is associated with the 110-ft interbed, and the contamination sources are the tank farm soil sources and OU 3-13, Group 3, soil sources. The highest observed Tc-99 concentrations were in well 33-1 at 690 pCi/L in 2004. High concentrations have also been measured in well MW-2 at 174 pCi/L in 1994 and 224 pCi/L in 2004. Concentrations in well MW-2 have been near 200 pCi/L since Tc-99 monitoring began in 1993 and continue to date. Well MW-5-2 has also had high observed Tc-99 concentrations, which have been near 100 pCi/L during the 1993-1995 time period but which have not been detected since 2001. The observations in the other northern upper shallow perched water wells have always been near or below 10 pCi/L. Tc-99 concentrations in the northern upper shallow perched water are not declining in all wells. They are persisting in well MW-2. The peak concentrations of Tc-99 in the northern shallow perched water most likely occurred early in the 1980s and the current concentrations are slowly tailing off.

Concentrations of Tc-99 were mostly overpredicted (Figure A-7-17). The higher simulated concentrations in the perched water wells surrounding the tank farm suggest that Tc-99 is not moving horizontally to the extent predicted by the model or the tank farm Tc-99 has already moved below the upper shallow perched water.

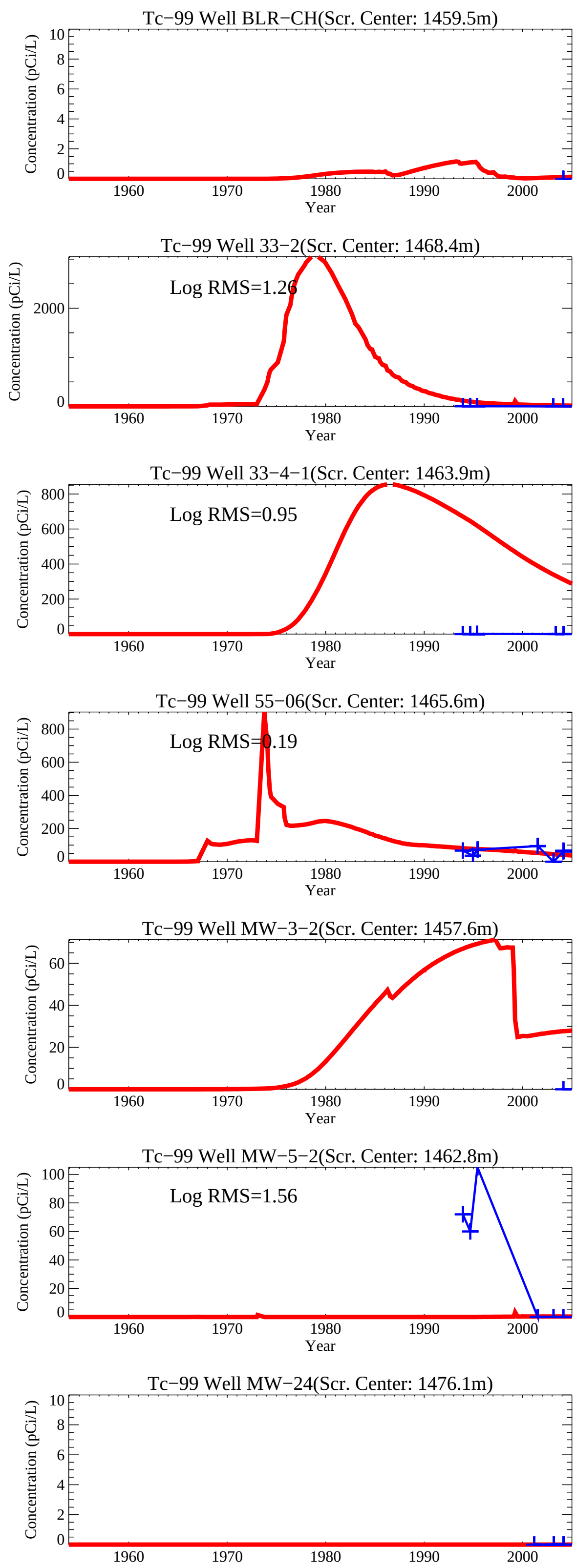

Figure A-7-17. Tc-99 concentrations in the northern upper shallow perched water (red line = simulated, blue crosses = observed, pCi/L).

A-7.3.1.2 Northern Lower Shallow Perched Water Tc-99

The northern lower shallow perched water is associated with the 140-ft interbed and the contamination source is primarily associated with tank farm releases. The highest observed Tc-99 concentrations are in well MW-10-2 (592 pCi/L in 1994, and 451 pCi/L in 2004). Concentrations in well MW-20-2 have been variable throughout the sampled period and have ranged from zero to 49 pCi/L. Observed concentrations in the BLR-SP and TF-SP have been below detection. The low and relatively constant concentrations seen in the field data suggest peak arrival occurred prior to the first observations in 1994.

The simulated and observed concentration patterns are similar to those in the northern upper shallow perched water. The highest concentrations are beneath the tank farm and immediately south and east of the tank farm. The simulated concentrations overpredict the observed values (Figure A-7-18). The large abrupt changes in concentration predicted to occur in the northern lower shallow perched water are due to the quarterly step change in simulated Big Lost River recharge. The wells nearest to the Big Lost River reflect a larger response (i.e., wells TF-SP and TF-CH). The model predicts the 140-ft interbed to be more directly affected by the river than is the 110-ft interbed (see Section A-7.2.2). This is because the slope of the 110-ft interbed beneath the river is away from the tank farm, but the slope of the 140-ft interbed is towards the tank farm.

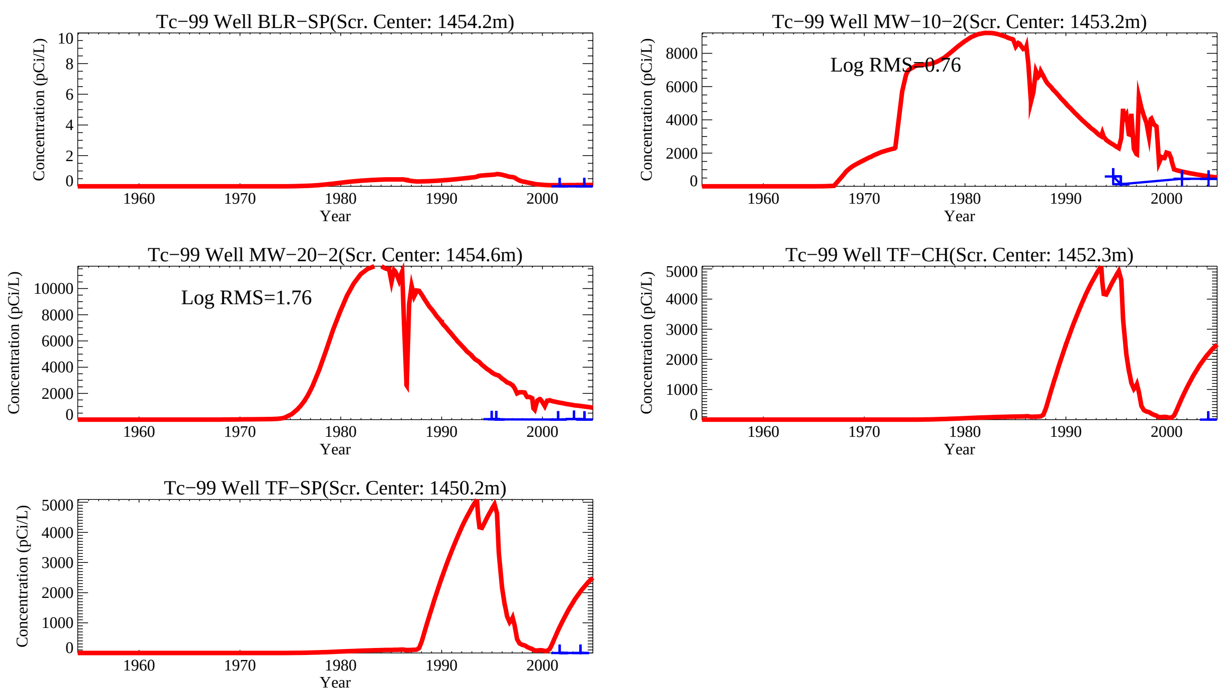

Figure A-7-18. Tc-99 concentration history in the northern lower shallow perched water (red line = simulated, blue crosses = observed, pCi/L).

A-7.3.1.3 Northern Deep Perched Water Tc-99

The northern deep perched water is associated with the 380-ft interbed and possibly with a low-permeability basalt. The contamination sources include the tank farm releases and service waste discharged in the CPP-3 injection well. The CPP-3 well casing collapsed in 1968 and, during the period 1968 through 1970, the service waste entered the deep vadose zone. The well casing may have been compromised much earlier than 1968, resulting in earlier vadose zone contamination. The highest observed Tc-99 concentrations were in well MW-18-1 (736 pCi/L), where only one observation was recorded in 1995. The background concentration of Tc-99 should be zero. Throughout the period recorded, concentrations in USGS-50 have been above background, and concentrations have been declining from a peak value of 77 pCi/L (1994) to 50.2 pCi/L (2001). Tc-99 concentrations in the BLR-DP well were below detection limits. The source of this Tc-99 is most likely from the failed injection well. In general, there is insufficient data to infer the arrival of Tc-99 originating from the tank farm sources in this region.

The simulated concentrations in MW-18-1 and well USGS-50 were several times higher than the observed values. The CPP-3 injection well casing began to fail in the early 1960s due to corrosion and was partially plugged by 1967. The well most likely discharged the service wastewater to the vadose zone during this time period (Buckham 1970). The model indicates that the vadose zone at the MW-18 and USGS-50 well locations appear to have been slightly impacted by the Tc-99 discharged to the CPP-3 well, but the later tank farm releases of Tc-99 had a much greater influence on water concentration. This is because tank farm Tc-99 sources were much larger than those discharged to the injection well during the simulated failure period. The tritium simulations showed the opposite, because the tank farm sources were much smaller than the injection well source.

The highest simulated deep perched water concentrations were under the eastern half of the tank farm and the high concentration area extended approximately 100 m southeast. The maximum simulated deep perched water concentration was approximately 3,000 pCi/L. The highest deep perched water concentrations were southeast of the tank farm near the MW-18 well and were not north of the tank farm near the ICPP-MON-A-230 well. Current aquifer concentrations in the ICPP-MON-A-230 and ICPP-2021 aquifer wells are above the Snake River Plain Aquifer maximum contaminant level and are as much as an order of magnitude higher than the simulated aquifer concentrations. The reason for this discrepancy is unknown but may be in part due to the CPP-1 and CPP-2 production well capture zone extending further south than that predicted by the aquifer model.

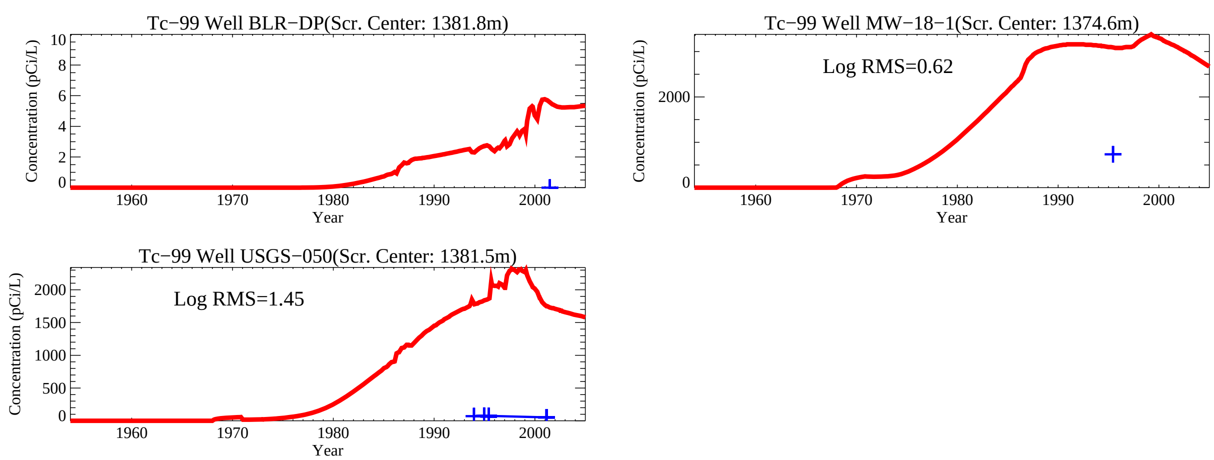

Figure A-7-19. Tc-99 concentration history in the northern deep perched water (red line = simulated, blue crosses = observed, pCi/L).

A-7.3.1.4 Southern Shallow Perched Water Tc-99

The southern shallow perched water is associated with the 110-ft and 140-ft interbeds. The primary source of Tc-99 should be the service waste discharged in the former percolation ponds. The percolation ponds operated from 1984-2002 and received low-level radioactive waste until the Liquid Effluent Treatment and Disposal (LET&D) facility became operational in 1993. Most of the data available in the southern shallow perched water was taken after year 2000, and concentrations are near zero.

The highest observed Tc-99 concentrations in the region occurred in well MW-15 (23.5 pCi/L in 1995). Tc-99 was sampled for in the shallow PW-series wells in 2001, and the measured concentrations were below detection. It is likely that Tc-99, discharged into the percolation ponds, had already moved below the shallow perched zone when the 2001 measurements were taken. The Tc-99 observed in well MW-15 is most likely from the percolation ponds.

Simulated concentrations in well MW-15 are similar in magnitude to the observed values (Figure A-7-20). The other wells have observed and simulated concentrations near zero, except well PW-1. The simulated increasing Tc-99 concentration seen in well PW-1 is from the OU 3-13 CPP-22 site located south of Building CPP-603. This site was placed in the model in 1990 and the source term for this site was very conservatively estimated. The model suggests that Tc-99 concentrations had been higher in the southern INTEC and were subsequently reduced after the LET&D facility became operational in 1993.

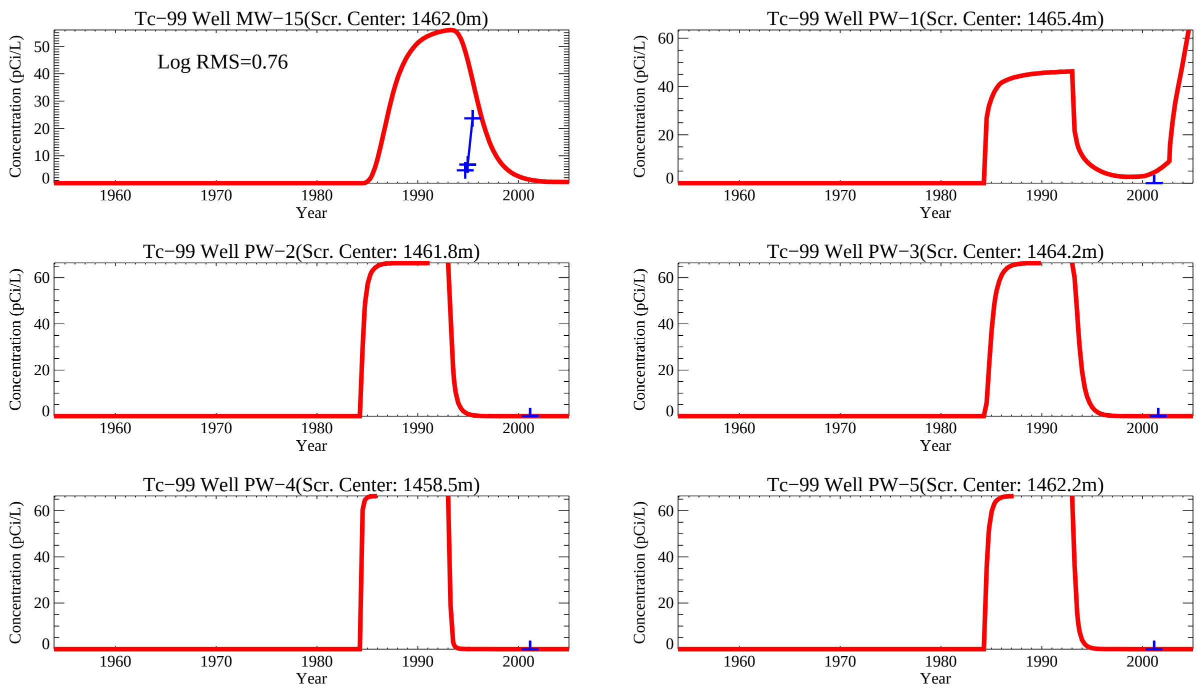

Figure A-7-20. Tc-99 concentration history in the southern shallow perched water (red line = simulated, blue crosses = observed, pCi/L).

A-7.3.1.5 Southern Deep Perched Water Tc-99

The southern deep perched water is associated with the 380-ft interbed, but perched water has been encountered higher than 380 ft. As with the southern shallow perched water, the primary source of Tc-99 is the former percolation ponds, with some contribution from the southern Group 3 soil sites. Wells MW-1-4 and CS-CH lie near the northernmost extent of the southern well grouping area and they most likely reflect a combination of CPP-3 injection well failure and tank farm releases. The highest observed Tc-99 concentrations in the southern deep perched water were found in the CS-CH well (10.6 pCi/L in 2001). Tc-99 has also been detected in wells MW-17-2 (6.4 pCi/L in 1995), MW-17-4 (5.2 pCi/L in 1995), and well MW-1-4 (2.1 pCi/L in 1994).

The simulated well 1807L receives Tc-99 from the CPP-22 soil site and from the percolation ponds. The deep perched water concentrations in well M-17 were very close to the simulated concentrations. The simulated and observed Tc-99 concentration histories in the southern deep perched water wells are illustrated in Figure A-7-21.

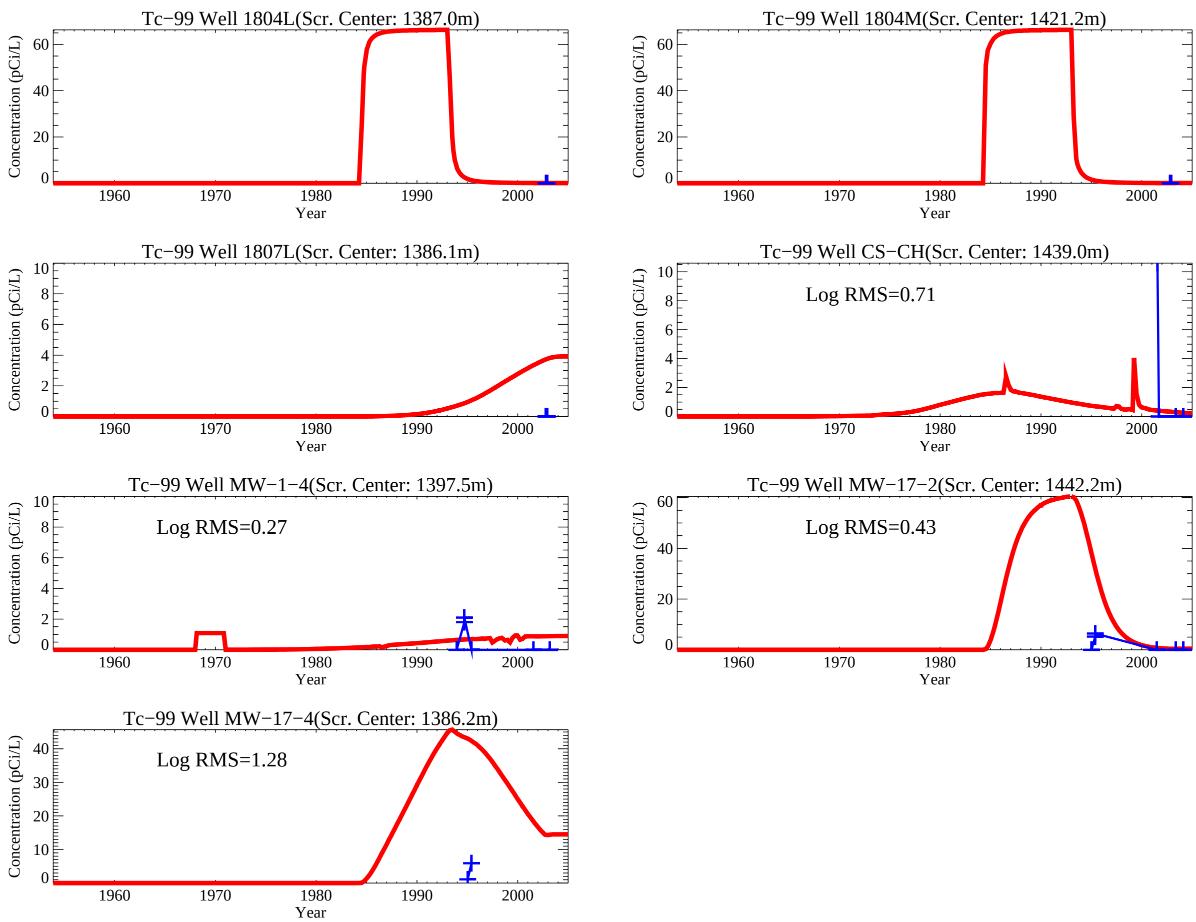

Figure A-7-21. Tc-99 concentration history in the southern deep perched water (red line = simulated, blue crosses = observed, pCi/L).

A-7.3.2 Tritium

The simulated vadose zone sources of tritium listed in order of decreasing magnitude are the service waste ponds (999 Ci), CPP-3 injection well failure (708 Ci), CPP-02 abandoned french drain (378 Ci), and the tank farm sources (10 Ci). Tritium concentrations are a good calibration target in the southern portion of INTEC, because of the relatively high concentrations, and a much worse calibration target in the northern portion of INTEC. The background tritium concentration is approximately 100 pCi/L in the Snake River Plain Aquifer (Orr et al. 1991) and simulated concentrations presented in this section were adjusted upwards by that amount to account for it. The simulated tritium concentrations are higher than the background concentration in most of the vadose zone located south of the tank farm.

Tritium is not adsorbed to the porous media but is significantly attenuated via decay as it migrates through the vadose zone. The half-life of tritium is 12.3 years and the water travel through the INTEC vadose zone can be several times greater, depending on the recharge rate and the location.

The arithmetic average log RMS and standard deviation for all well locations was 0.97 and 0.59, respectively. The minimum log RMS was 0.17 and the maximum was 2.1. Figure A-7-22 illustrates the arrival rate of tritium radioactivity in the aquifer. The peak corresponds to tritium injected in the deep vadose zone during the CPP-3 injection well failure. Tritium originating in the percolation ponds arrives in the early 1990s. The distribution of tritium predicted in the year 2004 is illustrated in Figure A-7-23. The high tritium concentrations located in the southern INTEC near well MW-17 is primarily from the CPP-02 site, which released approximately 378 Ci during the 1960s.

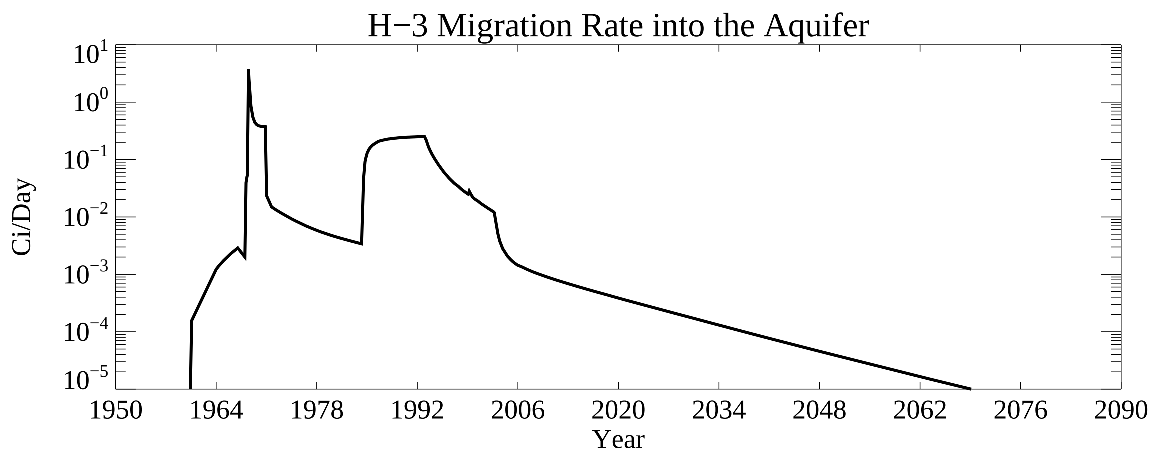

Figure A-7-22. Total flux of H-3 entering the aquifer (Ci/day).

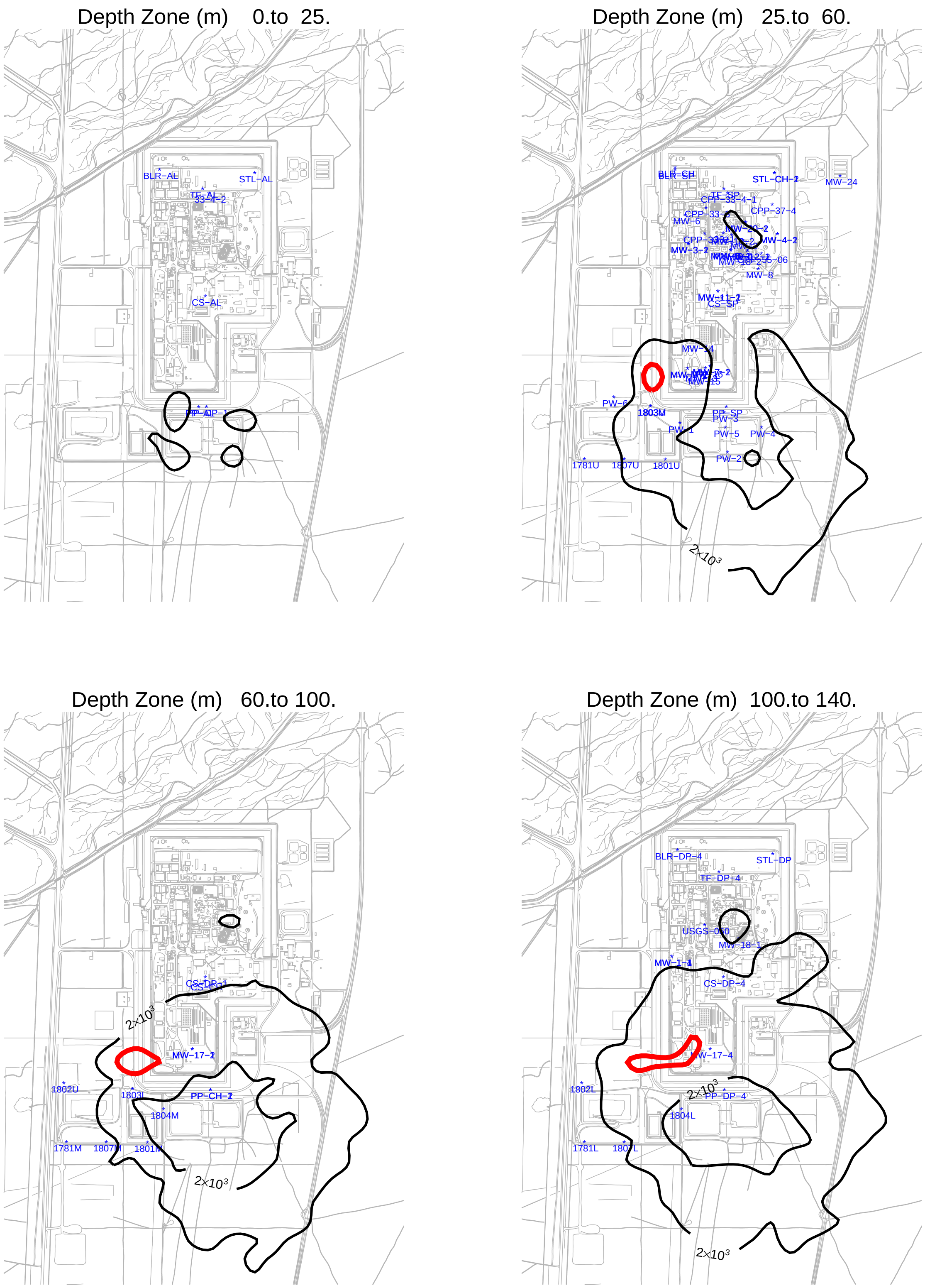

Figure A-7-23. Horizontal extent of simulated tritium at different depth intervals in 2004 (red isopleth is 20,000 pCi/L).

A-7.3.2.1 Northern Upper Shallow Perched Water Tritium

The highest observed tritium concentrations in the northern upper shallow perched water were in well MW-5-2. Concentrations in well MW-5-2 were 15,300 pCi/L in 1995 but were 569 pCi/L in 2004. There is only one observed tritium concentration value available for well 33-1: 9,900 pCi/L in 2004. High tritium concentrations have also been measured in well MW-2. They were measured at 6,380 pCi/L and 7,350 pCi/L in 1995 and 2004, respectively. The observed tritium concentrations in the other northern upper shallow perched water wells have been near or below 1,000 pCi/L.

A well-represented concentration history for tritium is unavailable (Figure A-7-24). Sampling began in the 1990s, and the bulk of tritium likely passed through this region prior to that. The peak tritium concentrations in this region most likely occurred in the late 1970s, and current observations probably represent the relatively flat tail. Concentrations are continuing to decline more rapidly than Tc-99 (also conservative or nonretarding) because of the 12.3-year tritium half-life.

The predicted concentration magnitudes in wells CPP-33-1, CPP-33-3, and MW-2 agree with measured data. The model overpredicted tritium concentrations in the MW-4-2 and MW-6 wells. The model also agreed with nondetects (i.e., near the 100-pCi/L background concentrations) at the BLR-CH and MW-24 wells. Overall, the simulated and observed tritium concentrations were similar in the northern upper shallow perched water.

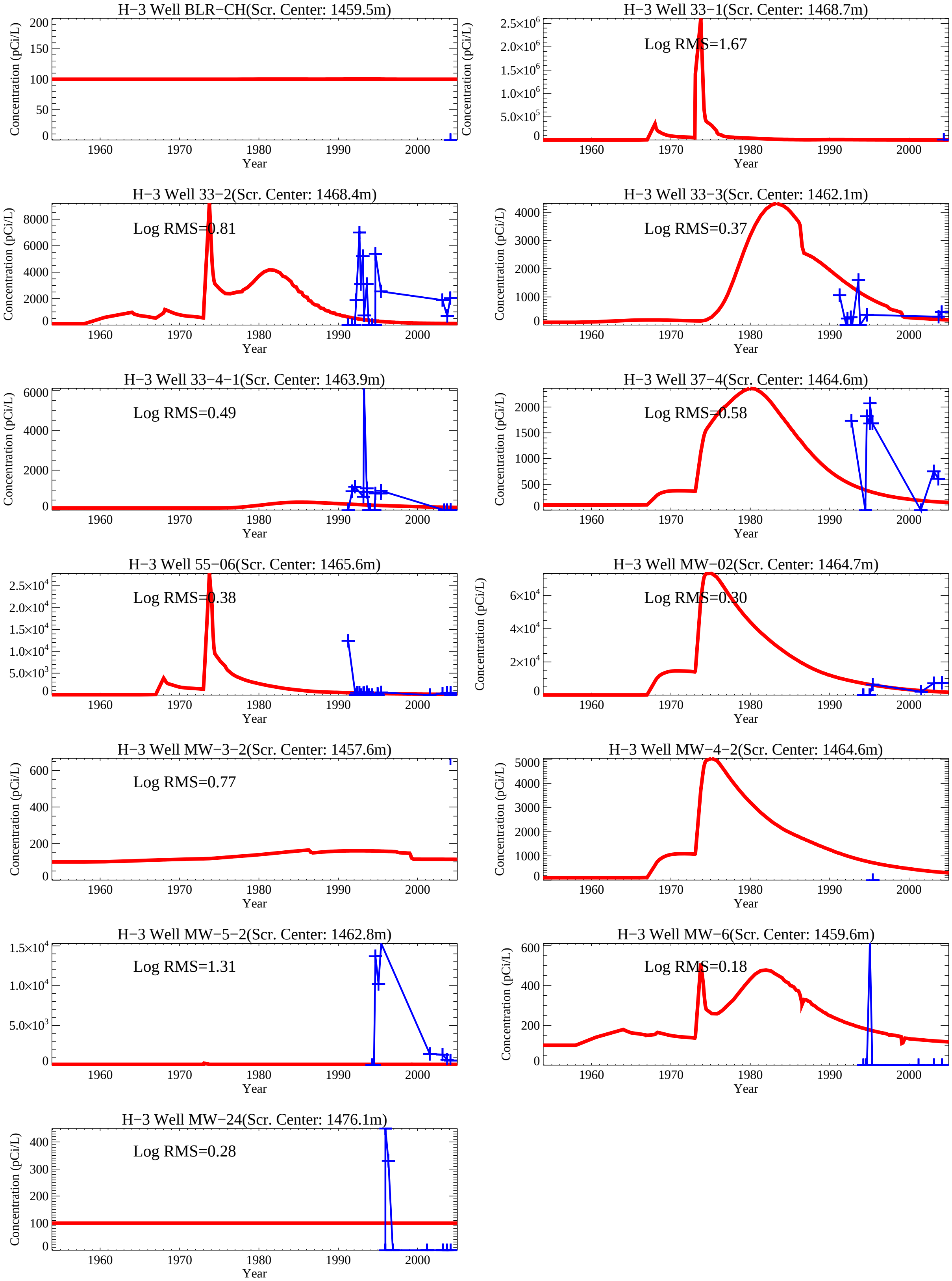

Figure A-7-24. Tritium concentration history in the northern upper shallow perched water (red line = simulated, blue crosses = observed, pCi/L).

A-7.3.2.2 Northern Lower Shallow Perched Water Tritium

The northern lower shallow perched water is associated with the 140-ft interbed, and the contamination source is primarily the tank farm releases. The highest measured tritium concentrations in this region occurred in well MW-10-2, were 38,000 pCi/L in 1995, and have declined to 13,000 pCi/L in 2004. The observed tritium concentrations were also high in well MW-20-2. The highest measured value was 1,150 pCi/L in 1995, and the 2004 concentration was less than the detection limit. The tritium concentrations in wells TF-SP and BLR-SP were nondetect, indicating tritium released in the tank farm does not reach these wells. The actual tritium concentrations in these wells should be near the background concentration. The two wells with high observed tritium concentrations (MW-10-2 and MW-20-2) indicate tritium concentrations are declining more rapidly than only radioactive decay. This suggests that the perched water is being recharged. The peak tritium concentrations most likely occurred before monitoring began.

The simulated and observed concentration patterns are similar to those in the northern upper shallow perched water (Figure A-7-25). The model matched tritium concentrations in well MW-20-2 but underpredicted concentrations in well MW-10-2. The model correctly predicted that tritium should be near background in the BLR-SP well. The large abrupt changes in concentration are due to the quarterly step change in the simulated Big Lost River recharge. The wells nearest to the Big Lost River show the largest change (i.e., wells TF-SP and TF-CH). The model predicts the 140-ft interbed is affected by the river to a greater extent than is the 110-ft interbed (see Section A-7.2.2).

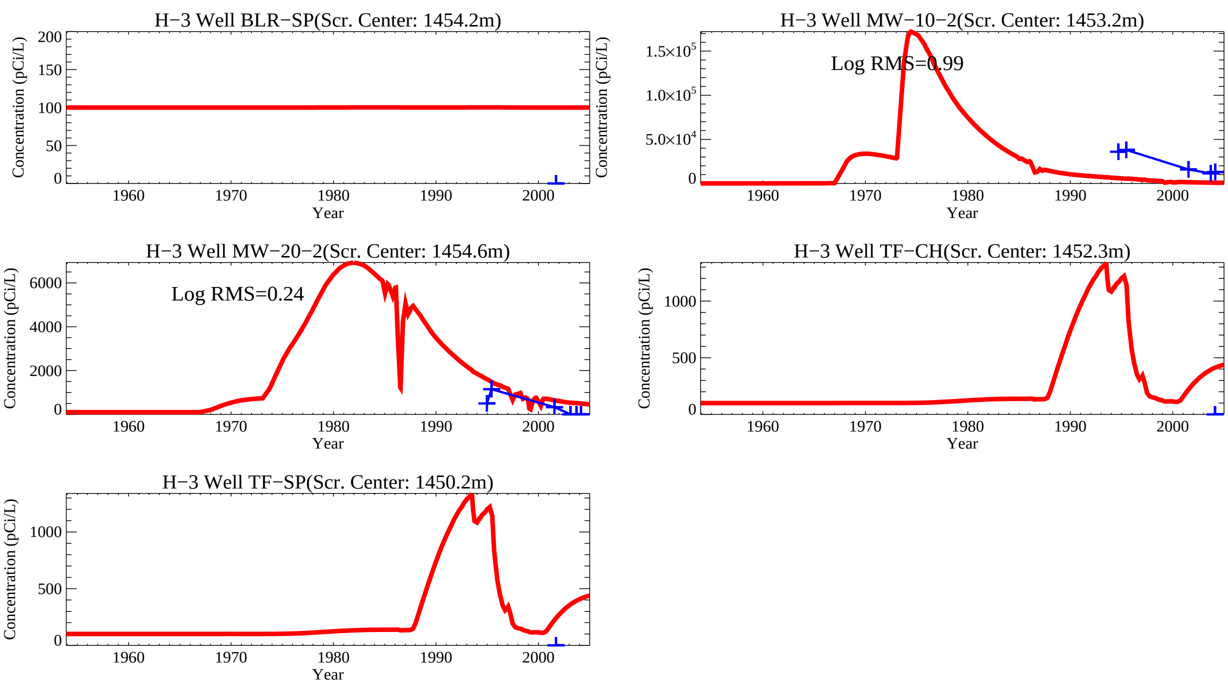

Figure A-7-25. Tritium concentration history in the northern upper shallow perched water (red line = simulated, blue crosses = observed, pCi/L).

A-7.3.2.3 Northern Deep Perched Water Tritium

As with Sr-90, the highest observed tritium concentrations (4,180,000 pCi/L) are associated with the CPP-3 injection well. Peak concentrations in USGS-50 have been declining steadily since 1980. However, there is more variability in the tritium concentrations relative to those of Sr-90, which is a reflection of the greater variability in the tritium service waste source.

Tritium concentrations were measured in well MW-18 during 1995 and 2001 and were 73,000 pCi/L and 34,900 pCi/L, respectively. USGS-50 and MW-18 had similar concentrations in 1995 and 2001. The observed concentration in well BLR-DP was only measured in 2001 and was below detection.

The early arrival of the observed and simulated tritium seen at well USGS-50 is from the CPP-3 injection well failure during the late 1960s. The simulation also suggests the area near MW-18 was impacted by service waste during the CPP-3 injection well failure, although monitoring data are unavailable during this time period.

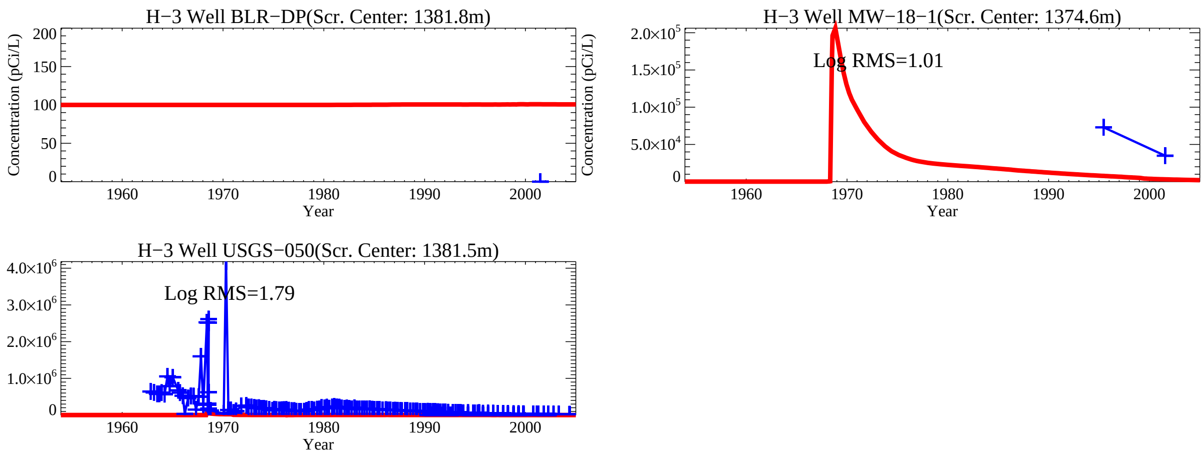

Figure A-7-26. Tritium concentration history in the northern deep perched water (red line = simulated, blue crosses = observed, pCi/L).

A-7.3.2.4 Southern Shallow Perched Water Tritium

The southern shallow perched water is associated with the 110-ft and 140-ft interbeds. The primary tritium contamination sources are the CPP-02 abandoned french drain and the former percolation ponds. The CPP-02 abandoned french drain operated from 1954 through 1966. The percolation ponds operated from 1984-2002 and received low-level radioactive waste until the LET&D facility became operational in 1993.

The highest observed tritium concentrations (100,000 pCi/L - 300,000 pCi/L) in this region were found in 1988 in the PW-series wells surrounding the former percolation ponds. After the LET&D facility was brought online in 1993, the tritium concentrations in the PW-series wells quickly declined to 100-1,000 pCi/L. The observed tritium concentration in well MW-15 was 3,630 pCi/L in 1995.

Most data collection in these wells began in the mid 1980s when the PW-series wells were installed. A definitive concentration history shows that the arrival of tritium in these wells is associated with the operation of the percolation pond (Figure A-7-27). Tritium discharge rates were much more variable than the discharge rates for Sr-90 in the service waste. The simulated discharges of tritium in the percolation pond were assumed to be constant throughout the discharge period, and, as a result, the model does not capture this variability (Figure A-7-27). High tritium concentrations observed in well PW-6 indicate the arrival of percolation pond water at that location, which was not predicted by the model.

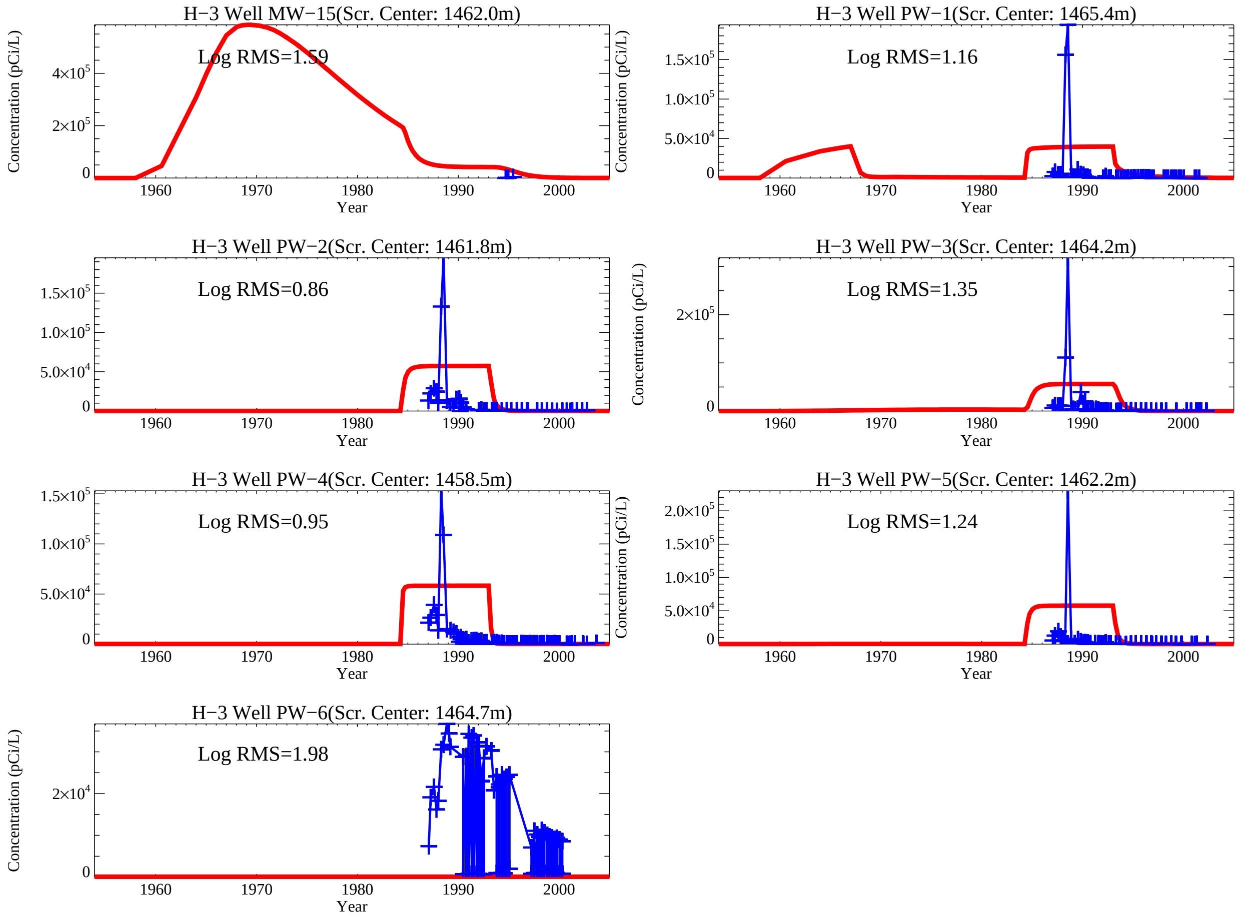

Figure A-7-27. Tritium concentration history in the southern shallow perched water (red line = simulated, blue crosses = observed, pCi/L).

A-7.3.2.5 Southern Deep Perched Water Tritium

The southern deep perched water is associated with the 380-ft interbed, but perched water has been encountered higher than 380 ft. As with the southern shallow perched water, the tritium contamination sources are the CPP-02 abandoned french drain and the service waste disposed of in the former percolation ponds. Wells MW-1-4 and CS-CH lie near the northernmost extent of the southern well grouping area, and they most likely see contamination resulting from the CPP-3 injection well; OU 3-13, Group 3, soil sources; and the tank farm releases.

The highest observed tritium concentrations in this region were found in MW-17-2 at 40,400 pCi/L in 2001. High concentrations also occurred in MW-1-4 (24,700 pCi/L in 1995) and MW-17-4 (25,100 pCi/L in 1995). Elevated tritium concentrations have been observed for many years in monitoring wells surrounding the CPP-603 area and is attributed primarily to past discharges of contaminated CPP-603 basin water to the alluvium during the 1960s (Robertson et al. 1974). The large decline in observed levels of shallow tritium between 1963 and 1970 supports this conclusion (INEL 1995b). Since that time, the tritium (and Sr-90) released into the alluvium has been transported downward to the shallow and deep perched water zones. Sr-90 and tritium derived in the shallow vadose zone continue to be transported to greater depth by precipitation infiltration and clean water discharges, such as the 2005 discovery of an underground fire water line leak near the southeast corner of CPP-603. However, because tritium is not appreciably adsorbed to clays, tritium concentrations decline more rapidly than Sr-90. During four successive monitoring events, tritium concentrations in southern perched monitoring well MW-17-2 have declined steadily from 40,400 pCi/L (2001) to 21,000 pCi/L (2005). This suggests that, aside from the residual secondary source in the contaminated alluvium, no other continuing tritium source is present in this area.

Tritium was below the 20,000 pCi/L federal drinking water standard but above the detection limit in wells 1804L at 8,200 pCi/L in 2002; well 1807L at 1,110 pCi/L in 2002, and CS-CH at 776 pCi/L in 2001. The simulated and observed tritium concentrations in the southern deep perched water wells are illustrated in Figure A-7-28.

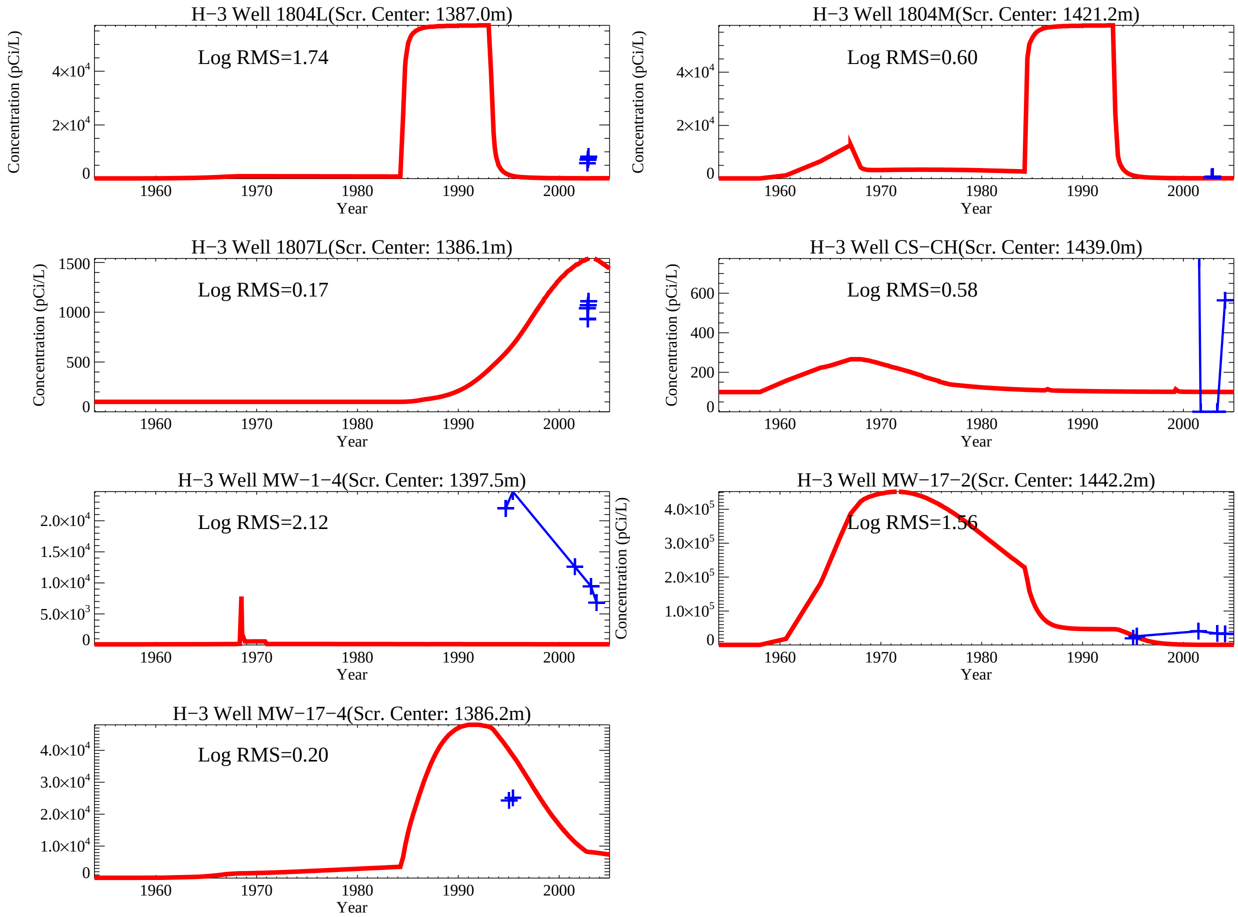

Figure A-7-28. Tritium concentration history in the southern deep perched water (red line = simulated, blue crosses = observed, pCi/L).

A-7.3.3 I-129

The simulated sources of vadose zone I-129 listed in order of decreasing magnitude are the CPP-3 injection well failure (0.075 Ci), service waste ponds (0.082 Ci), and tank farm sources (0.002 Ci). The background I-129 concentration is approximately 0.05 pCi/L in the Snake River Plain Aquifer (Orr et al. 1991). The simulated concentrations were adjusted to account for the background concentrations by adding this amount to the simulated value. Like Tc-99, I-129 is long-lived and very mobile in the subsurface. On average, the I-129 detection limit is a much larger fraction of the observed concentration than other contaminants. This results in more nondetects where concentrations are lower than the detection limit, but not zero. All nondetects were compared to the model values as a zero measured concentration. This results in the model appearing to overpredict I-129 movement relative to the other radionuclides. The arithmetic average log

RMS and standard deviation for all well locations was 1.4 and 2.0, respectively. The minimum log RMS was 0.3 and the maximum was 8.2.

Like tritium, I-129 is volatile compared to Sr-90 and Tc-99 at the high temperatures encountered in the calcination process. The bulk of the I-129 that began in the fuel was contained in the first-cycle raffinate and sent to the tank farm. During the calcination process, very little of the volatile was contained within the calcine. The bulk (approximately 90%) of it was discharged to the atmosphere with the calciner off-gas. However, most of the I-129 that does get into the PEW evaporator volatilizes, is condensed with the dilute condensate stream, and was discharged to service waste. This is approximately 10% of the I-129 originally in the fuel. This accounts for the relatively large source magnitude in the percolation ponds and CPP-3 disposal well, compared to the tank farm sources. The simulated I-129 is widespread in the northern deep vadose zone and southern vadose zone because of the CPP-3 injection well failure and the former percolation ponds.

Figure A-7-29 illustrates the total flux of I-129 arriving in the aquifer over time. The highest peak corresponds to the CPP-3 injection well failure and occurred in the late 1960s. Arrival from the surface releases is predicted to have occurred in the early 1990s. Predicted concentrations in the vadose zone in 2004 are given at different depth intervals in Figure A-7-30. The I-129 concentrations illustrated in Figure A-7-30, which extend in the deep vadose zone from the northern to the southern INTEC, include sources from the tank farm in the north, failed CPP-3 injection well in the central INTEC, and percolation ponds in the south. The plotted data is pore water concentrations and includes unsaturated zones.

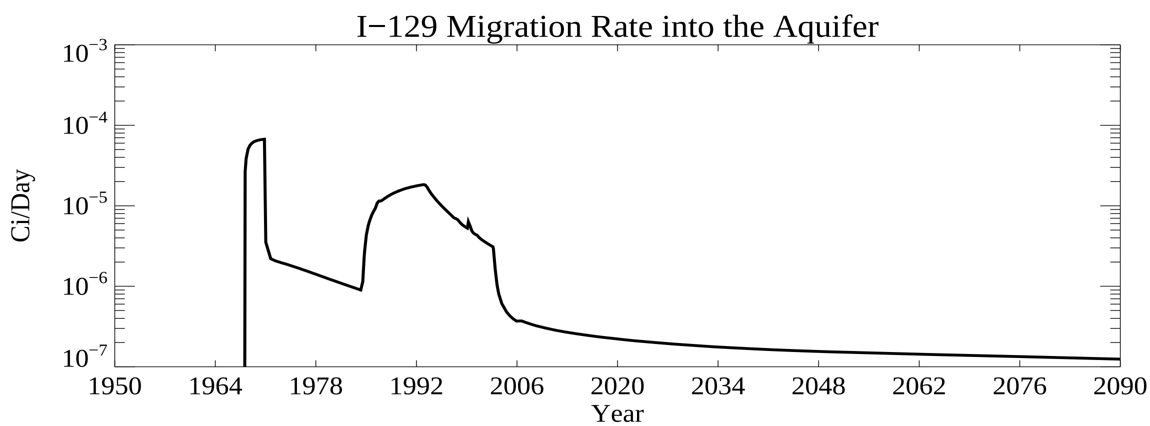

Figure A-7-29. Total flux of I-129 entering the aquifer (Ci/day).

Figure A-7-30. Horizontal extent of simulated I-129 at different depth intervals in 2004 (pCi/L).

A-7.3.3.1 Northern Upper Shallow Perched Water I-129

The northern upper shallow perched water is associated with the 110-ft interbed and the primary source is from the tank farm releases. The observed I-129 concentrations in the northern shallow perched water have always been very low. The highest observed I-129 concentrations are in well MW-5-2 and were 0.18 and 0.71 pCi/L in 2001 and 2003, respectively. Isolated concentrations above 1 pCi/L were observed in wells CPP-33-1 and MW-24 during the early 1990s. Peak I-129 concentration most likely occurred in the early 1980s as illustrated in Figure A-7-31.

The recorded concentration-time data began after the peak arrival of I-129 in this region. The early measurements were probably performed using an analytical method with a corresponding high detection limit compared to in situ concentrations. The 13-pCi/L observation in MW-24 is relatively high and probably did not originate in the known tank farm releases.

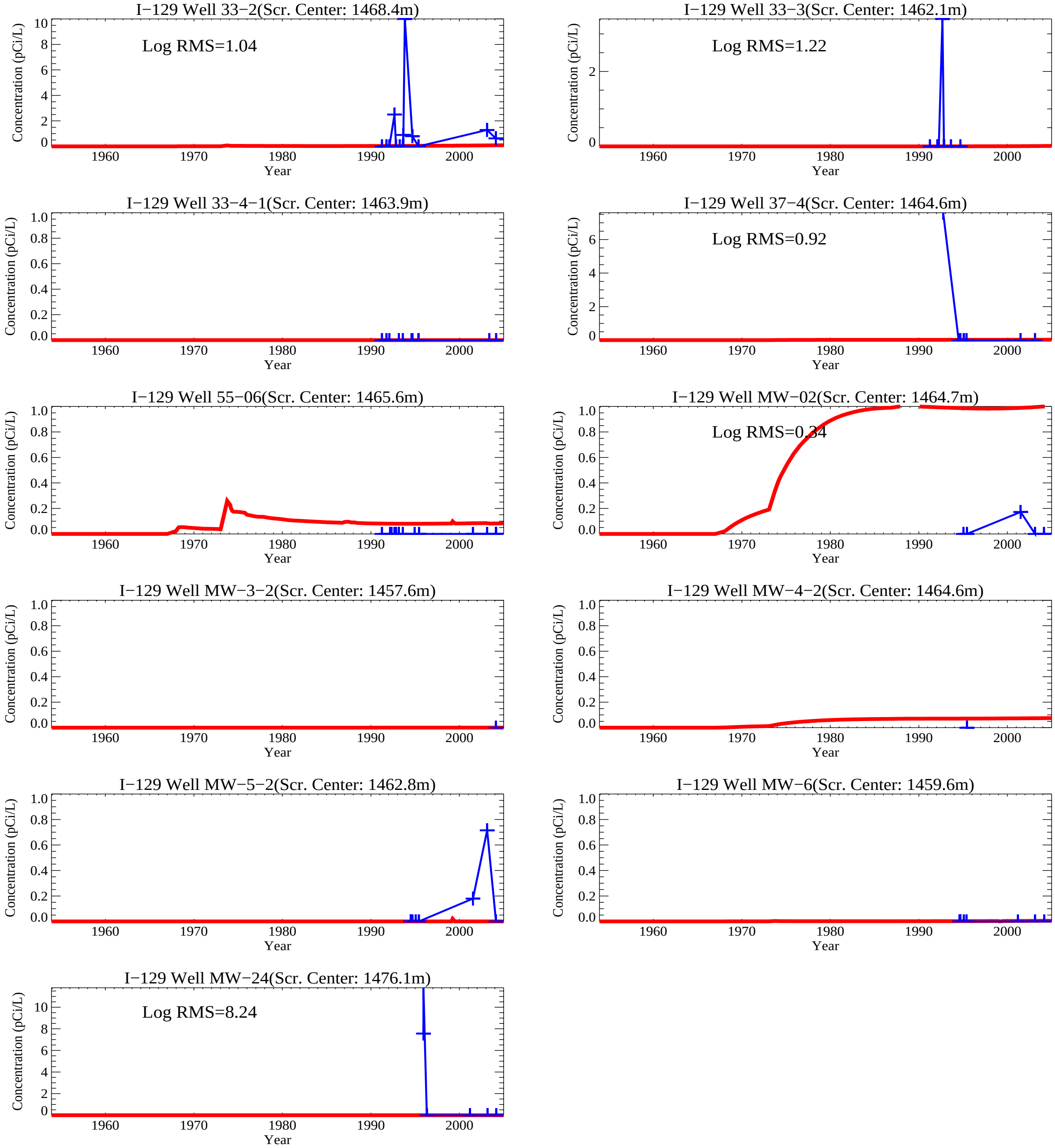

Figure A-7-31. I-129 concentration history in the northern upper shallow perched water (red line = simulated, blue crosses = observed, pCi/L).

A-7.3.3.2 Northern Lower Shallow Perched Water I-129

The northern lower shallow perched water is associated with the 140-ft interbed and the contamination sources are primarily the tank farm releases. All of the data in this perched water were nondetect. The simulated concentration patterns are similar to those predicted for the northern upper shallow perched water, and the model overpredicts those values for one well, MW-10-2, as shown in Figure A-7-32.

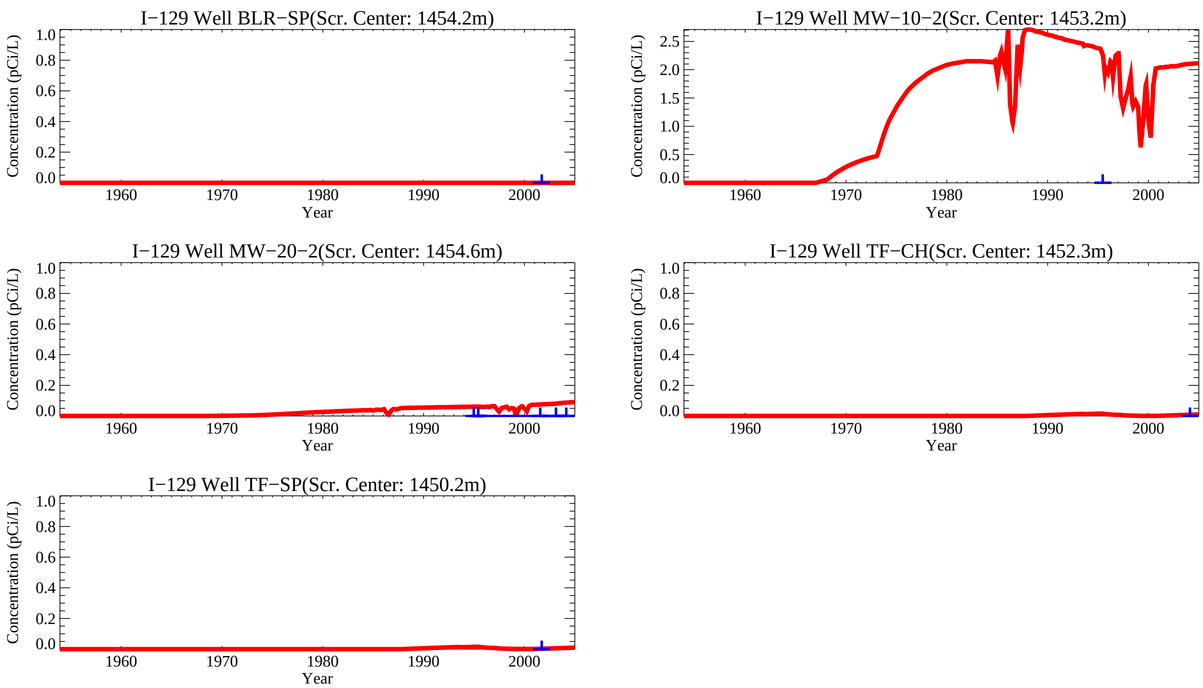

Figure A-7-32. I-129 concentration history in the northern lower shallow perched water (red line = simulated, blue crosses = observed, pCi/L).

A-7.3.3.3 Northern Deep Perched Water I-129

The northern deep perched water is associated with the 380-ft interbed and possibly a low-permeability basalt. The contamination sources include the tank farm releases and the CPP-3 injection well during the 1968-1970 failure period. The well casing may have been compromised much earlier than 1968, which would have allowed earlier contamination of the vadose zone. The highest observed I-129 concentrations in the northern deep perched water were observed in well USGS-50. A 1.1-pCi/L concentration was measured in 1995 and 0.56 pCi/L was measured in 2004. The concentrations in well MW-18 and BLR-DP were below detection in 1995 and in 2001. The I-129 in well USGS-50 is most likely remnants of the CPP-3 injection well failure and I-129 discharge to the deep vadose zone.

Monitoring for I-129 was not performed frequently enough to reproduce the I-129 concentration history as illustrated in Figure A-7-33.

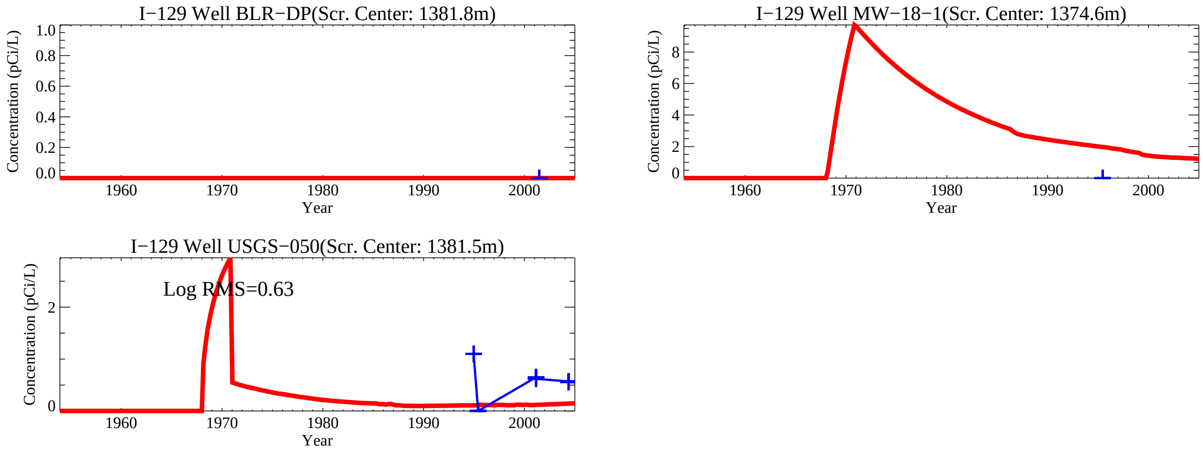

Figure A-7-33. I-129 concentration history in the northern deep perched water (red line = simulated, blue crosses = observed, pCi/L).

A-7.3.3.4 Southern Shallow Perched Water I-129

The southern shallow perched water is associated with the 110-ft and 140-ft interbeds. The primary contamination source is the former percolation ponds. The percolation ponds operated from 1984-2002, and the percolation ponds received significant amounts of low-level radioactive waste until the LET&D facility became operational in 1993. The PW-series wells were installed in the mid-1980s, but were not monitored for I-129 until the mid-1990s. This was after the LET&D facility became operational and I-129 concentration in the service waste water was near zero.

The highest observed I-129 concentrations in this region were found in the PW-series wells surrounding the former percolation ponds. Well PW-5 had the highest observed I-129 concentrations at 4.26 pCi/L in 1996. I-129 concentrations in the other PW series wells and well MW-15 were less than 1 pCi/L. All of the observed I-129 data in the southern shallow perched water postdates the LET&D facility (1993). It is likely that the service waste I-129 has already moved below the southern shallow perched water. The simulated and observed I-129 concentrations are illustrated in Figure A-7v34.

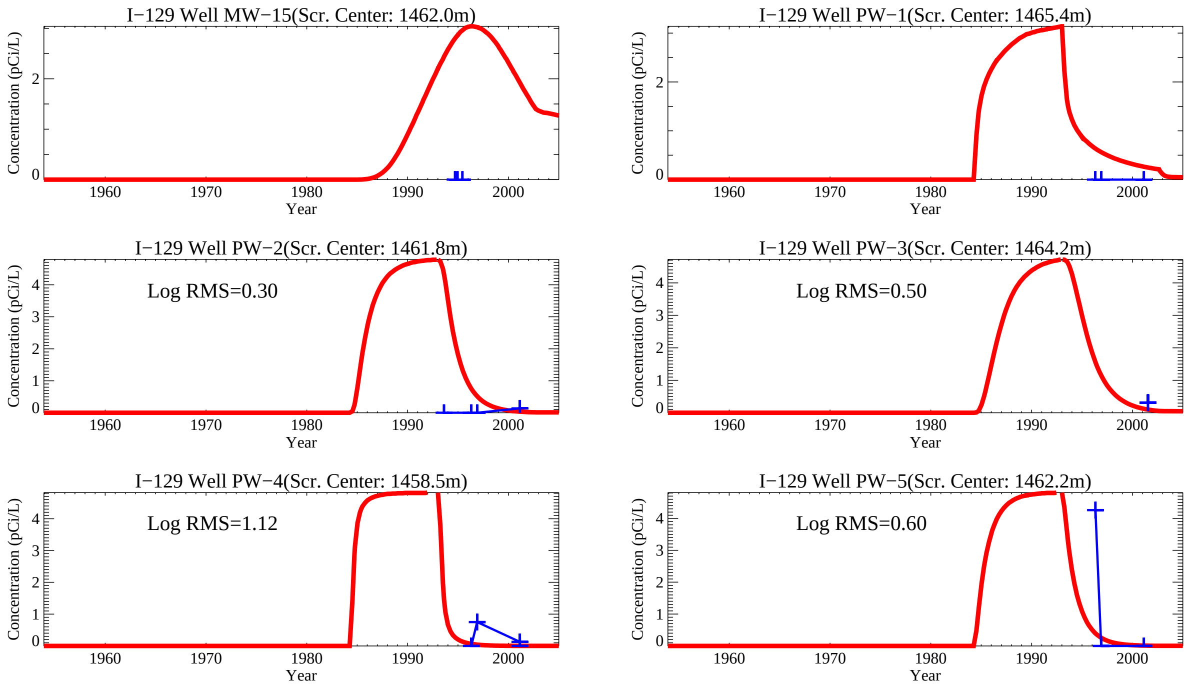

Figure A-7-34. I-129 concentration history in the southern shallow perched water (red line = simulated, blue crosses = observed, pCi/L).

A-7.3.3.5 Southern Deep Perched Water I-129

The southern deep perched water is associated with the 380-ft interbed, but perched water has been encountered higher than 380-ft. As with the southern shallow perched water, the I-129 contamination source is the former percolation ponds. Wells MW-1-4 and CS-CH lie near the northernmost extent of the southern well grouping area and they most likely see I-129 resulting from the CPP-3 injection well; OU 3-13, Group 5, soil sources; and possibly the tank farm releases.

The highest observed I-129 concentrations in the southern deep perched water were found in well 1804M at 0.402 pCi/L in 2002. I-129 concentrations above the detection limit were also measured in wells 1804L at 0.368 in 2002, and 1807L at 0.355 pCi/L in 2002. The postyear 2000 slight increasing trend seen in the simulated concentration at well MW-17-4 is due to I-129 from the failed CPP-3 injection well slowly dispering towards this well. Figure A-7-35 illustrates the simulated and measured I-129 concentrations in the southern deep perched water wells.

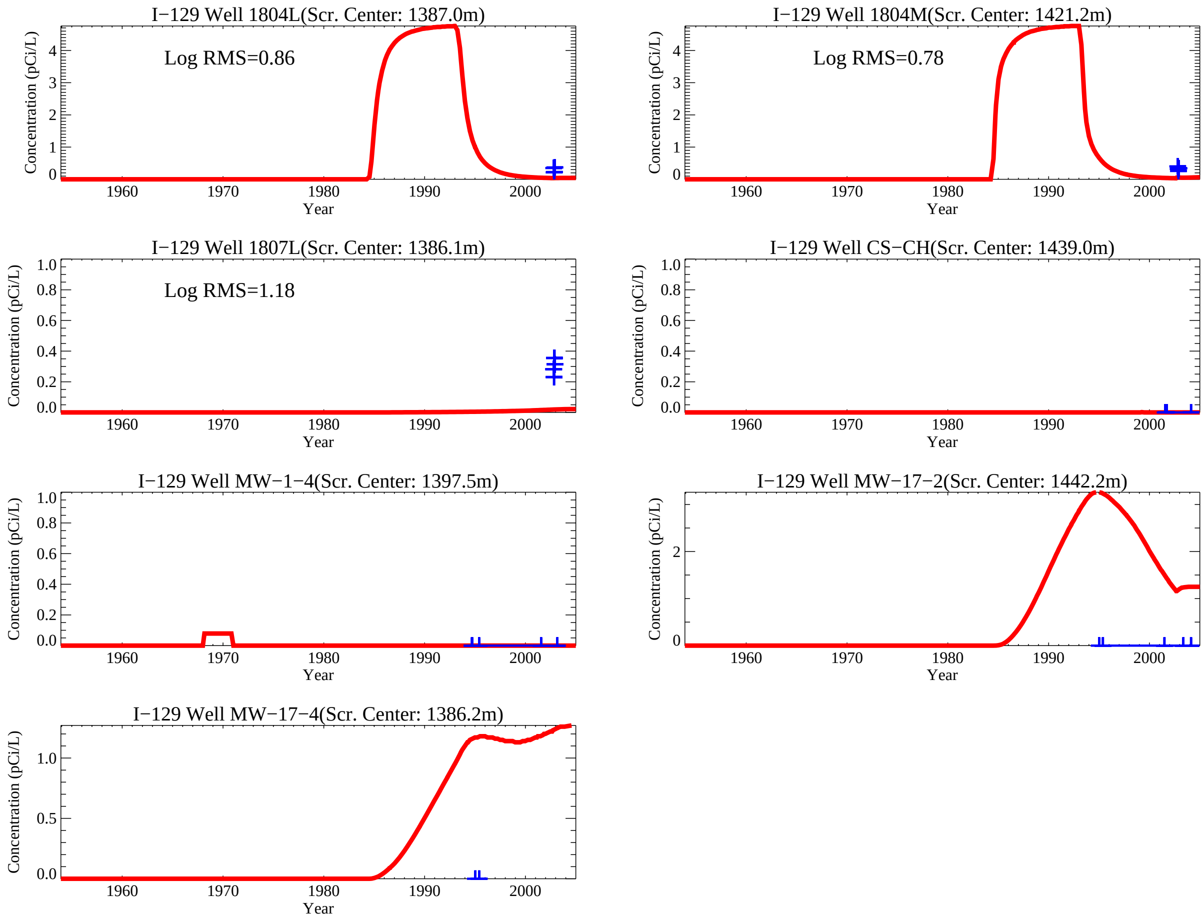

Figure A-7-35. I-129 concentration history in the southern deep perched water (red line = simulated, blue crosses = observed, pCi/L).

A-7.3.4 Nitrate

The spent nuclear fuel was dissolved in either nitric or hydrofluric acid during the uranium recovery process at INTEC, resulting in a large amount of nitrate in the liquid waste. The nitrate is very mobile in the subsurface and does not decay. The simulated sources of vadose zone nitrate listed in order of decreasing magnitude are the service waste ponds (1.3e + 6 kg), CPP-3 injection well failure (2.2e + 5 kg), and tank farm sources (2.1e + 4 kg). The nitrate (NO_3-) ion is ubiquitous in most groundwaters, and the Snake River Plain Aquifer background concentration is approximately 1.5 mg/L as N (Orr et al. 1991). The perched water background nitrate concentration should be similar to those in the aquifer because very little nitrification occurs in the INL Site vadose zone and much of the water responsible for creating the perched water was taken from the aquifer. The simulated concentrations were adjusted to account for the background concentrations by adding this amount to the simulated value.

In many of the tank farm perched water wells, a classic concentration history was observed during the early 1990s. There are no known nitrate discharges accounted for during this time period. As a result, the model underpredicted nitrate concentrations in most of the perched water wells around the tank farm.

The service waste nitrate discharges were two orders of magnitude greater than the known tank farm sources and have resulted in widespread concentrations above background in the northern deep and southern perched water. The arrival of nitrate at the aquifer interface is illustrated in Figure A-7-36. The early nitrate peak corresponds to the injection well failure, and the later peak is the arrival of percolation pond discharges. Figure A-7-37 illustrates nitrate concentrations at different depth intervals in the vadose zone. The arithmetic average log RMS and standard deviation for all well locations was 1.0 and 1.7, respectively. The minimum log RMS was 0.07 and the maximum was 1.7.

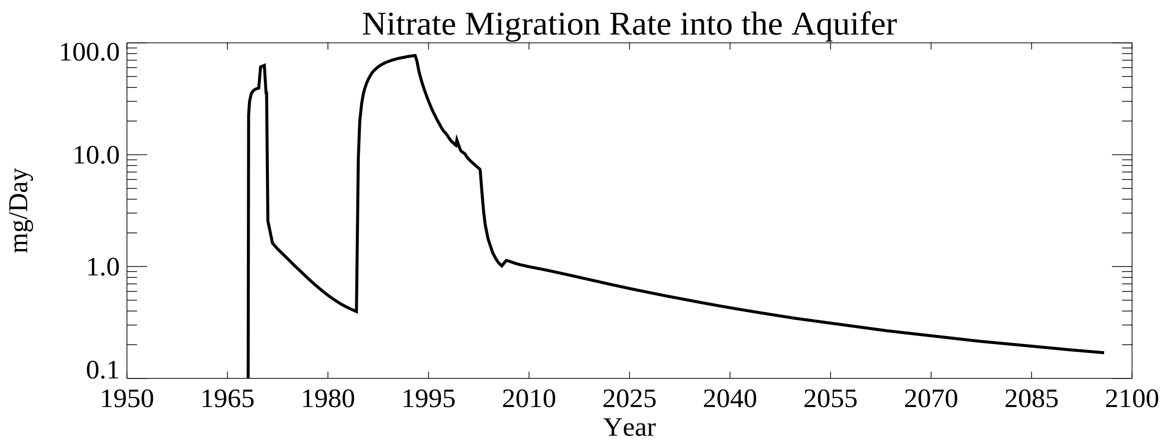

Figure A-7-36. Total flux of nitrate entering the aquifer (kg/day).

Figure A-7-37. Horizontal extent of simulated nitrate at different depth intervals in 2004 (mg/L as N).

A-7.3.4.1 Northern Upper Shallow Perched Water Nitrate

The northern upper shallow perched water is associated with the 110-ft interbed and the source of nitrate is primarily from the historical tank farm releases. The highest observed nitrate concentrations in this region have been observed in well MW-5-2. Concentrations in this well increased from 17.8 mg/L as N to 147 mg/L as N from 1991 to 1993 and then declined to 6.2 mg/L in 2001. The CPP-33-3, MW-6, and MW-2 wells also experienced a peak in nitrate during the early 1990s, but at a lower magnitude. Observed nitrate concentrations in well MW-24 are also high compared to background concentrations. However, the elevated concentrations from well MW-24 are most likely from the sewage treatment lagoon infiltration trench and not from the tank farm releases. Nitrate originating in the tank farm probably reached this region during the early 1980s. The source of the nitrate peaks observed in the early 1990s is unknown and was not matched with the model.

The CPP-31 site was the largest source of tank farm nitrate at 1.92e+4 kg. The CPP-79 site release occurred in 1986 but was orders of magnitude less than the CPP-31 release. The simulated Site CPP-31 nitrate can be seen arriving in the early1980s, but there are no measured data until the early 1990s. The high observed nitrate in well MW-24 near the sewage treatment lagoon is most likely a result of sewage plant effluent. The model did not incorporate a sewage nitrate source and did not match the observed concentration at this location. The simulated and observed nitrate concentration in the northern upper shallow perched water wells is illustrated in Figure A-7-38.

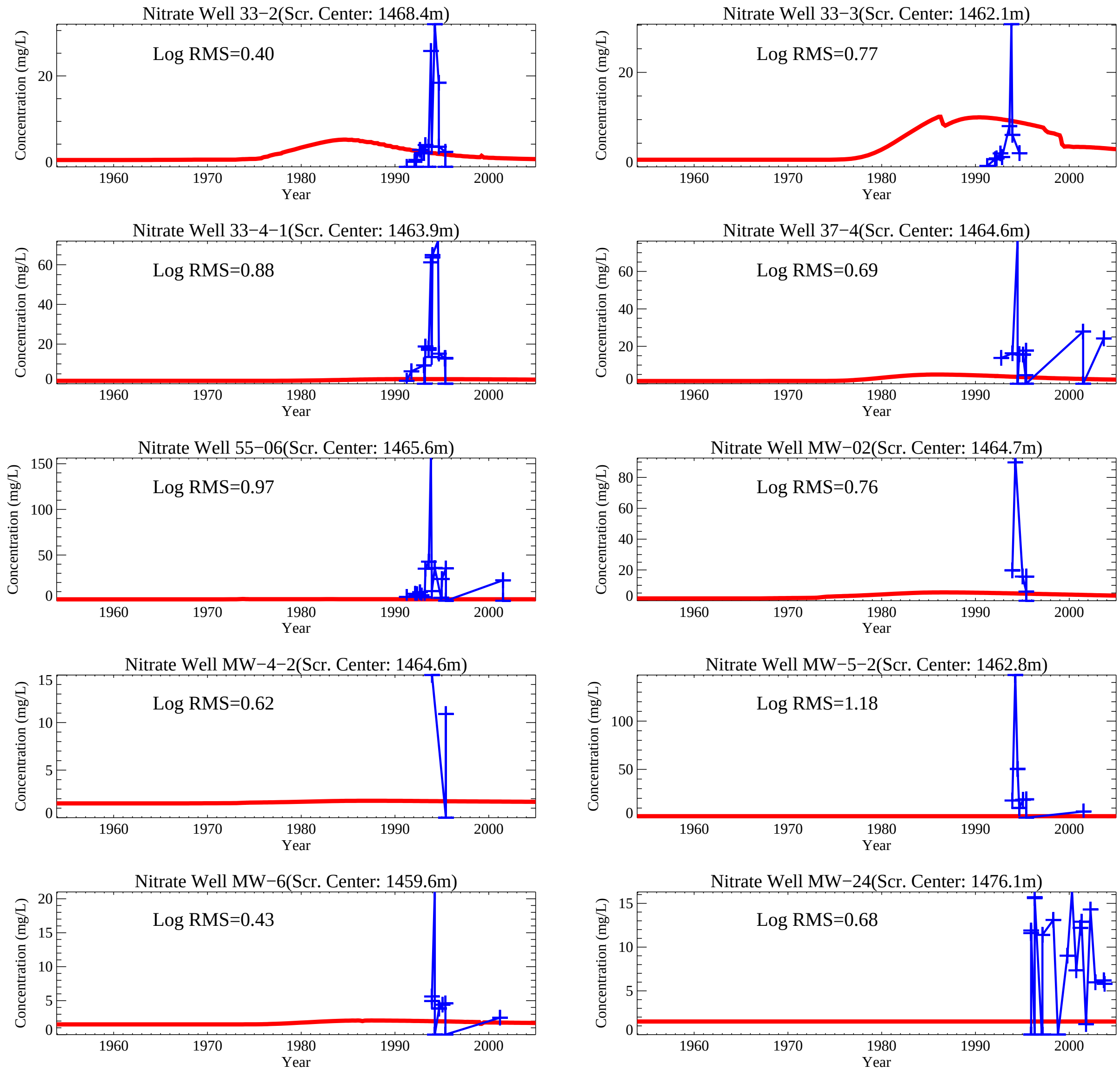

Figure A-7-38. Nitrate concentration history in the northern upper shallow perched water (red line = simulated, blue crosses = observed, mg/L as N).

A-7.3.4.2 Northern Lower Shallow Perched Water Nitrate

The northern lower shallow perched water is associated with the 140-ft interbed and the contamination source is primarily the tank farm releases. The simulated and observed concentration patterns are similar to those predicted in the northern upper shallow perched water. The observed concentrations in the two northern lower shallow perched water wells monitored for nitrate were above background. The highest concentrations were in well MW-10-2 at 27.4 mg/L as N in 1994. Well MW-20-2 had a maximum concentration of 12.4 mg/L as N in 1994. Concentrations in both wells were variable and ranged from the maximum value to zero and randomly ranged above and below the simulated concentrations. There are insufficient data in the two northern lower shallow perched water wells to determine concentration trends through time. The simulated and observed nitrate concentrations in this region are illustrated in Figure A-7-39.

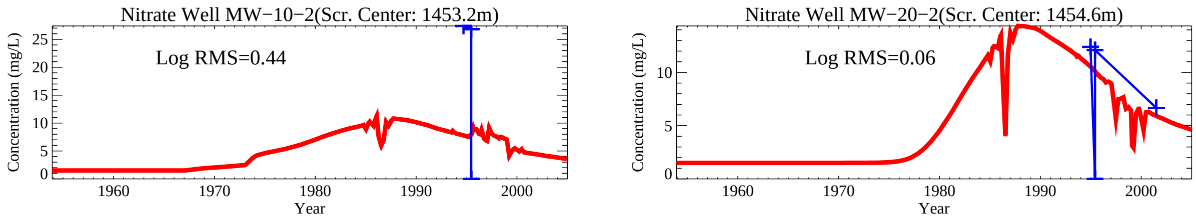

Figure A-7-39. Nitrate concentration history in the northern lower shallow perched water (red line = simulated, blue crosses = observed, mg/L as N).

A-7.3.4.3 Northern Deep Perched Water Nitrate

The northern deep perched water is associated with the 380-ft interbed and possibly with a low-permeability basalt. The nitrate sources include the tank farm releases and the CPP-3 injection well. The highest observed nitrate concentrations in the northern deep perched water were recorded in well USGS-50. The measured concentrations were 54.8 mg/L as N in 1993 and concentrations had declined to 36.5 mg/L as N in 2001 (Figure A-7-40). Nitrate was also above background concentrations in well MW-18 at 34.5 mg/L as N in 1995. The most recent nitrate concentrations recorded in wells USGS-50 and MW-18 could be either remnants of the CPP-3 injection well failure or from the tank farm releases. The simulated and observed nitrate concentrations in well BLR-DP are at background concentrations.

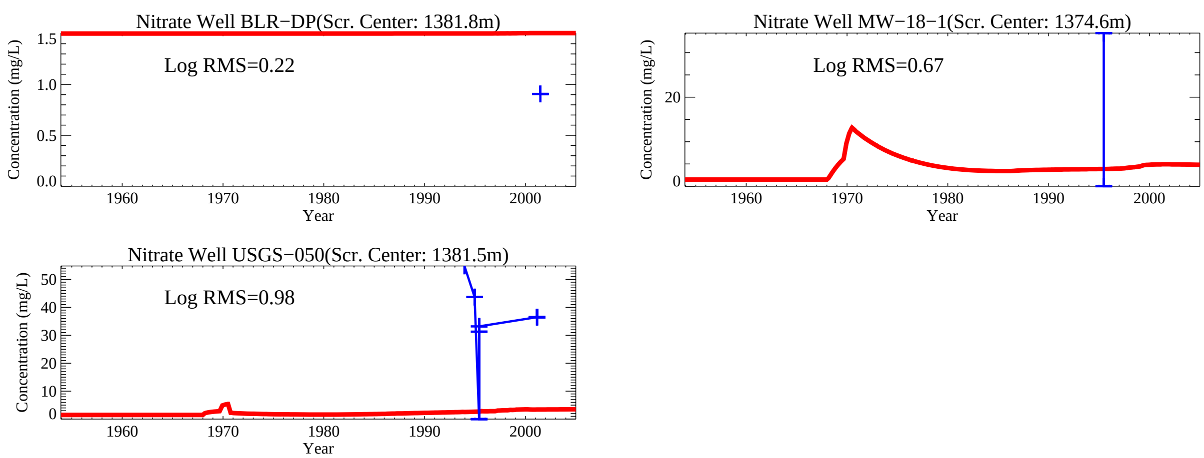

Figure A-7-40. Nitrate concentration history in the northern deep perched water (red line = simulated, blue crosses = observed, mg/L as N).

A-7.3.4.4 Southern Shallow Perched Water Nitrate

The southern shallow perched water is associated with the 110-ft and 140-ft interbeds. The primary nitrate contamination source is the service waste discharged to the former percolation ponds.

The highest observed nitrate concentrations were in well MW-15. The maximum observed value was 14.7 mg/L as N in 1995. Nitrate concentrations in the other southern shallow perched water wells were near the background concentration (1.5 mg/L as N) or nondetect. Like the I-129 observations, all of the data postdates 1993, the operational start of the LET&D facility. The nitrate originating in the percolation ponds has likely already moved below the southern shallow perched water.

The PW-series wells were installed in the mid-1980s but were not monitored for nitrate until after the LET&D facility became operational in 1993. The observed nitrate concentrations were near background in all the southern shallow perched water wells except well MW-15. The observed concentrations ranged above and below the simulated concentrations in well MW-15. The simulated and observed nitrate concentration in the southern shallow perched water wells is illustrated in Figure A-7-41.

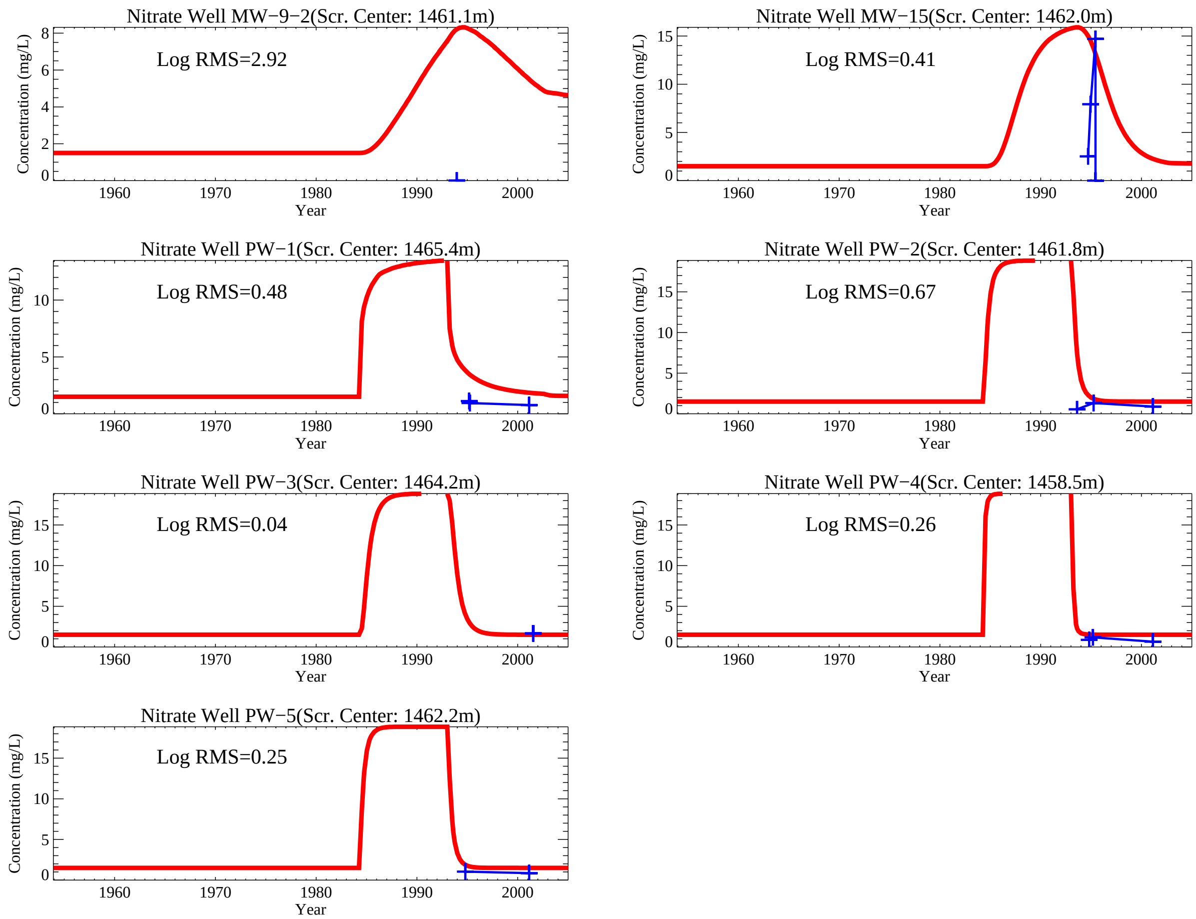

Figure A-7-41. Nitrate concentration history in the southern shallow perched water (red line = simulated, blue crosses = observed, mg/L as N).

A-7.3.4.5 Southern Deep Perched Water Nitrate

The southern deep perched water is associated with the 380-ft interbed, but perched water has been encountered higher than 380 ft. As with the southern shallow perched water, the nitrate contamination source is from the former percolation ponds. Wells MW-1-4 and CS-CH lie near the northernmost extent of the southern well grouping area, and they most likely see contamination resulting from the CPP-3 injection well and the tank farm releases.

The highest observed nitrate concentrations in the southern deep perched water were found in well MW-1-4 at 694 mg/L as N in 1993. Nitrate concentrations were much lower in the southern perched water wells surrounding the percolation pond. The only other southern deep perched water well with nitrate concentrations above the 10-mg/L federal drinking water standard was well MW-17-2 at 15.4 mg/L as N in 1995. However, nitrate was also measured in wells CS-CH at 8.14 mg/L as N in 2001, MW-17-4 at 4.6 mg/L as

N in 1994, 1804M at 0.99 mg/L as N in 2002, 1807L at 0.67 mg/L as N in 2002, and 1807L at 0.62 mg/L as N in 2002.

The model agrees with the magnitude of observed nitrate concentration except for well MW-1-4. The observed 1993 concentration of 694 mg/L may be an error because observations immediately before and after this date were approximately 70 mg/L. The simulated and observed nitrate concentrations in this region are illustrated in Figure A-7-42.

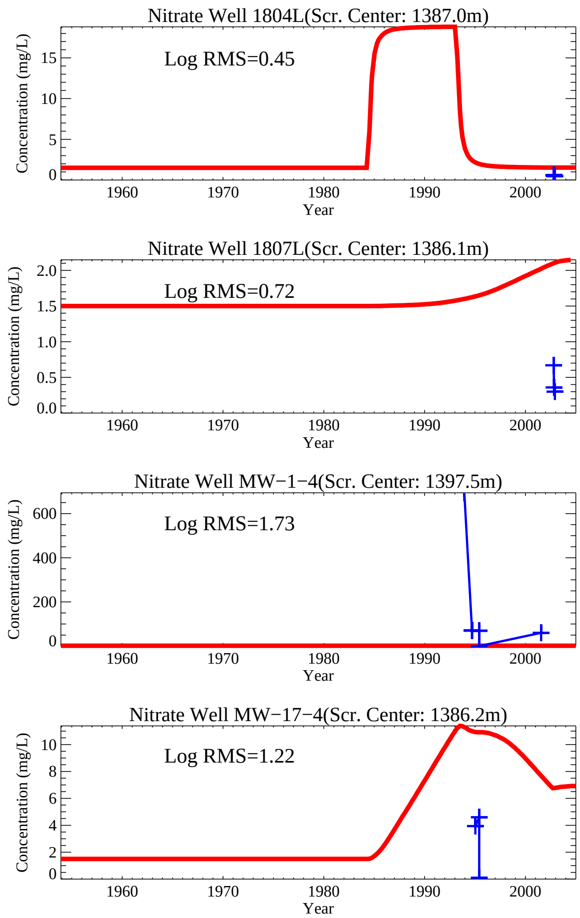

Figure A-7-42. Nitrate concentration history in the southern deep perched water (red line = simulated, blue crosses = observed, mg/L as N).

A-7.3.5 Transport Calibration Conclusions

The primary objective of the vadose zone transport calibration was to match the timing and concentration of contaminants in the perched water bodies and aquifer resulting from the tank farm soil contamination. The transport calibration was achieved by adjustment of hydraulic parameters, source term placement, and dispersivity. The source term placement adjustment was only performed if the contamination site straddled two model grid blocks.

The highest observed contaminant concentrations in the northern shallow perched water are located south, east, and southeast of the tank farm in wells CPP-33-1, MW-2, MW-10-2, MW-20-2, MW-5, and CPP-55-06. This can be seen in the predicted and observed concentration histories presented in Section A-7.3. The model is consistent with this general trend.

The perched water monitoring wells surrounding the tank farm are on the perimeter of the main contaminant flow path to the aquifer and may not sample the highest concentrations resulting from the tank farm leaks and spills. This may explain how simulated aquifer concentrations (Tc-99 in particular) are higher than those obtained in the deep perched water wells surrounding the tank farm, because the perched water wells may not sample the highest perched water concentrations directly under the tank farm.

The Tc-99 simulations indicate the water travel time from the tank farm land surface to the aquifer is approximately 30 years. The water travel time from other areas of the INTEC can be much faster (i.e., the percolation pond travel time was approximately 2 years). During high flow years, the Big Lost River can have a very large impact on contaminant transport rates.

There are insufficient data for conclusive model calibration in the deep vadose zone. Conclusive model calibration requires knowledge of the source strength and release timing in addition to measurements of the concentration history at the locations of calibration. Most often, data collection in the perched water wells began after the peak was predicted to occur. Data collection for the slower-moving contaminants has been taken over periods too short to discern the relative position on the concentration history.

The simulated concentrations were mostly higher than the observed concentrations in the shallow perched water surrounding the tank farm. The higher simulated-than-observed contaminant concentrations suggest that contaminants are not moving horizontally to the extent predicted by the model. This also implies that the model may be underestimating perched water concentrations immediately below the tank farm. However, there are no wells directly below the tank farm to confirm this. For these reasons, the model could underestimate peak aquifer contaminant concentrations.

Although the model has several deficiencies, it adequately represents the bulk movement of tank farm contaminants from land surface to the aquifer and is a significant improvement over the previous modeling studies. The INTEC vadose zone is a complex heterogeneous environment that will always have monitoring results that represent local spatial variabilities and fast pathways that a large-scale equivalent porous media model will not represent.

A-7.4 Summary of Vadose Zone Model Assumptions

The following list contains the primary assumptions used in developing the vadose zone flow and transport models:

- The infiltration rate study presented in Appendix B is adequate for representing precipitation recharge through disturbed and unvegetated INTEC sediments and the recharge from precipitation is steady state.

- The Big Lost River loss rate between the INL Site diversion dam and the Lincoln Boulevard bridge gauging station represents the loss rate near INTEC, and quarterly averages adequately represent transient river recharge.

- Big Lost River recharge prior to 1985 and after 2004 is steady state and is adequately represented by the long-term average between 1965 through 1987.

- The INTEC water balance presented in the OU 3-13 RI/BRA (DOE-ID 1997) is adequate for representing the pre-remedial conditions with the exception of Big Lost River and precipitation recharge.

- The INTEC water balance presented in the INTEC Water System Engineering Study (DOE-ID 2003b) and the Waste Calcining Facility water discharge study (DOE-ID 2004b) are adequate for representing the anthropogenic post-remedial action water sources.

- The surficial sediments and interbeds have spatially varying surfaces and thicknesses that influence water and contaminant movement.

- Six material types (high- and low-permeability alluvium, interbed, and basalt) adequately represent subsurface heterogeneity.

- Flow in the fractured basalt was controlled by the fracture network and could be represented by a high-permeability, low-porosity equivalent porous medium.

- All contaminant sorption processes can be lumped into a single soil/water distribution coefficient (K_d) parameter for each COC.

- Perched water elevation is adequate for calibrating the vadose zone flow model.